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SOME ASPECTS OF THE MELTING AND CRYSTALLIZATION OF ROCK-FORMING MINERALS*

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INTRODUCTION

Minerals are interesting because of the story they tell of those complex physical and chemical processes that have operated in the building and modification of our earth and its crust. One of the most fascinating problems of earth science is the delineation of the physical chemistry of the crystallization of rock-forming minerals from magmas.

The rock magma—a molten solution of complex silicates—is the parent source of the igneous rocks and their minerals. Many igneous rock types may result from the cooling and crystallization of this magma.

Much information on the processes involved in igneous-rock origin has been obtained from detailed petrographic examinations of samples of igneous rocks and from geological field data on the interrelations of the various rocks. However, in order to understand and interpret the complex phenomena of crystallization, with changing mineral assemblages responding to changes in thermodynamic environment brought about by cooling or by changes in pressure, it has been necessary to study the phase equilibrium relations in a large number of silicate systems. Fundamental information concerning the mode of origin of the minerals of the igneous rocks has been obtained through the preparation of silicate melts (simplified artificial magmas) in the laboratory with controlled variations of chemical composition, and a study of the behavior of these melts at equilibrium under a wide variety of temperature and pressure conditions.

We have been particularly interested in the mutual melting and crystallization relations, which cause changes in chemical composition and crystal system in response to changing temperature conditions, of the olivines, the pyroxenes and pyroxenoids (especially those containing

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* At the request of the Council, Dr. J. F. Schairer has prepared this Presidential address, which because of the cancellation of the annual meeting was not presented orally. Although heavily burdened with war work the author has kindly consented to prepare, on short notice, this general survey article which we are pleased to present at this time. The Editors.

FeO) and the melilites. We have also been interested in the direction of change of chemical composition of the residual liquid phase as crystallization proceeds in artificial melts that may approach the compositions of natural magmas.

All of the important rock-forming minerals of the igneous rocks, with the exception of quartz, have a variable composition. They are solid solutions which undergo progressive changes in chemical composition during cooling and crystallization of the magma. Even when there are no interruptions in the cooling cycle, there are continuous or discontinuous changes in the compositions of individual minerals and in the kinds of minerals crystallizing from the liquid phase. A mineral or assemblage of minerals stable at an early stage in the crystallization process may become unstable at a later stage and undergo transformation to new mineral assemblages with changes in both chemical composition and crystal system.

Of the various oxides that enter into the composition of the minerals of the igneous rocks, SiO_2, Al_2O_3, iron oxides, MgO, CaO, Na_2O and K_2O are of greatest importance. In order to obtain the desired information concerning the processes involved in the crystallization of a rock magma, one by one the fundamental unary, binary and ternary systems of rock-forming oxides have been studied in the laboratory. Studies of four of the quaternary systems which include these oxides are in progress. We propose to review briefly what progress has been made from a study of artificial silicate melts towards the understanding of the crystallization chemistry of three groups of rock-forming minerals—the olivines, the pyroxenes and related pyroxenoids and the melilites.

OLIVINES

The olivines are a series of polycomponent orthosilicate solid solutions. Most rock-forming olivines consist essentially of the two molecules forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4). Other molecules which may be present in rock-forming olivines are Ca_2SiO_4 (which exists in at least two crystalline modifications, one of which is the monoclinic mineral larnite), merwinite ($Ca_3Mg(SiO_4)_2$, monoclinic), monticellite ($CaMgSiO_4$), Fe-monticellite ($CaFeSiO_4$), tephroite (Mn_2SiO_4) and glaucochroite ($CaMnSiO_4$).

Bowen and Schairer[1] studied the system $MgO–FeO–SiO_2$. By means of a series of isothermal planes they showed in detail the compositions of all liquid and solid phases from the liquidus temperatures to below 955°C. and discussed the paths of crystallization of typical liquids. Their studies on this system showed the chemical compositions, optical properties and mutual melting and stability relations of three sets of solid solutions—the magnesia-iron olivines, the magnesia-iron pyroxenes and the magnesio-wüstites (MgO–FeO solid solutions). Their equilibrium diagram for the magnesia-iron olivines is given here as Fig. 1.

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[1] Bowen, N. L., and Schairer, J. F., The system $MgO–FeO–SiO_2$: *Am. Jour. Sci.*, **29**, 151–217 (1935).

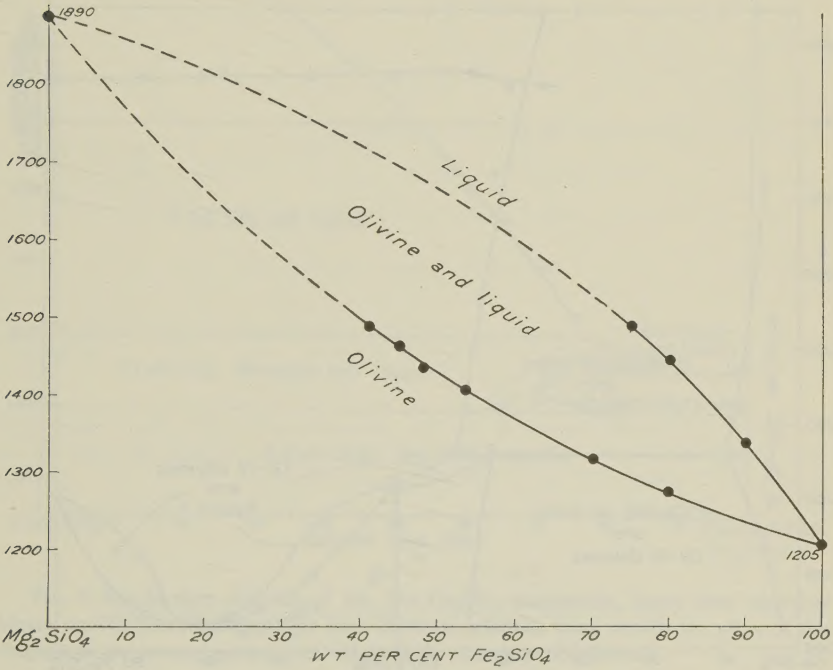

FIG. 1. Equilibrium diagram of the binary system Mg_2SiO_4–Fe_2SiO_4.
(Diagram of Bowen and Schairer.)

In like manner, Bowen, Schairer and Posnjak[2] in two papers presented their study of the system CaO–FeO–SiO_2 with data on the chemical compositions, optical properties and mutual melting and stability relations of two sets of solid solutions—the lime-iron olivines with compositions between Ca_2SiO_4 and Fe_2SiO_4 and the lime-iron pyroxenes and pyroxenoids with compositions between $CaSiO_3$ and $FeSiO_3$. By means of a series of isothermal planes, they showed in detail the compositions of all liquid and solid phases from the liquidus temperatures to 700°C. and discussed the paths of crystallization of typical liquids. Their equilibrium diagram for the system Ca_2SiO_4–Fe_2SiO_4 is given here as Fig. 2.

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[2] (a) Bowen, N. L., Schairer, J. F., and Posnjak, E., The system Ca_2SiO_4–Fe_2SiO_4: *Am. Jour. Sci.*, **25**, 273–297 (1933); (b) The system CaO–FeO–SiO_2: *ibid.*, **26**, 193–284 (1933).

Some years ago, Ferguson and Merwin[3] presented data for the system $CaO-MgO-SiO_2$. The composition join $Ca_2SiO_4-Mg_2SiO_4$ cuts this system. They established the incongruent nature of the melting of monticellite ($CaMgSiO_4$) and show a field of monticellite solid solutions on the liquidus surface in the ternary system. Recently, Osborn[4] has made some

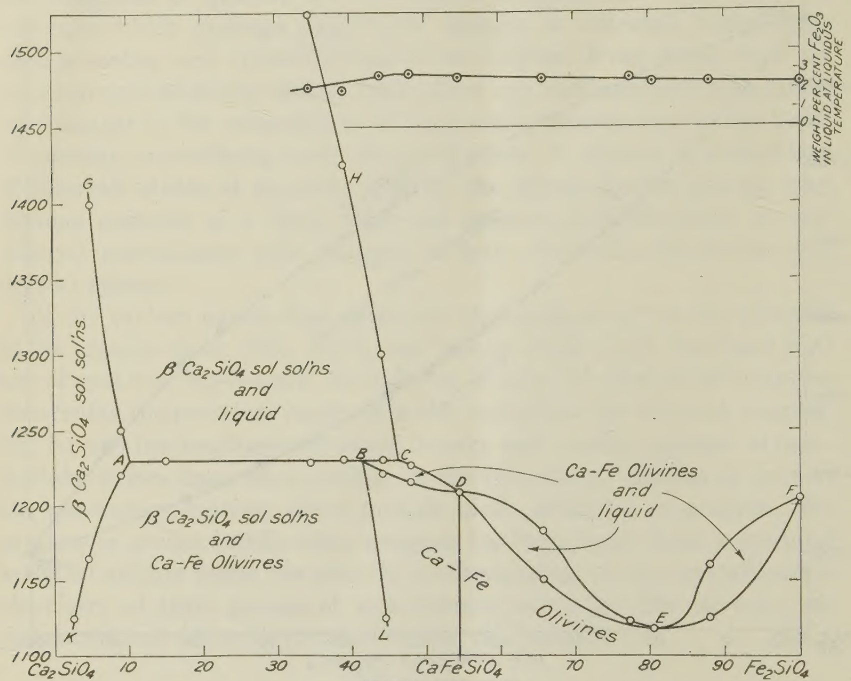

FIG. 2. Equilibrium diagram of the binary system $Ca_2SiO_4-Fe_2SiO_4$. (Diagram of Bowen, Schairer and Posnjak.)

corrections to the diagram for $CaO-MgO-SiO_2$, including stability data on the orthosilicate merwinite which melts incongruently and has a field on the liquidus surface in the ternary system. Preliminary data suggest that there is limited solid solution extending from Ca_2SiO_4 toward merwinite. His diagrams for Ca_2SiO_4–akermanite and merwinite–akermanite are reproduced here as Figs. 3 and 4, respectively.

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[3] Ferguson, J. B., and Merwin, H. E., The ternary system $CaO-MgO-SiO_2$: *Am. Jour. Sci.*, **48,** 81–123 (1919).

[4] Osborn, E. F., The compound merwinite ($3CaO \cdot MgO \cdot 2SiO_2$) and its stability relations within the system $CaO-MgO-SiO_2$. (Preliminary report.): *Jour. Am. Ceram. Soc.*, **26,** 321–332 (1943).

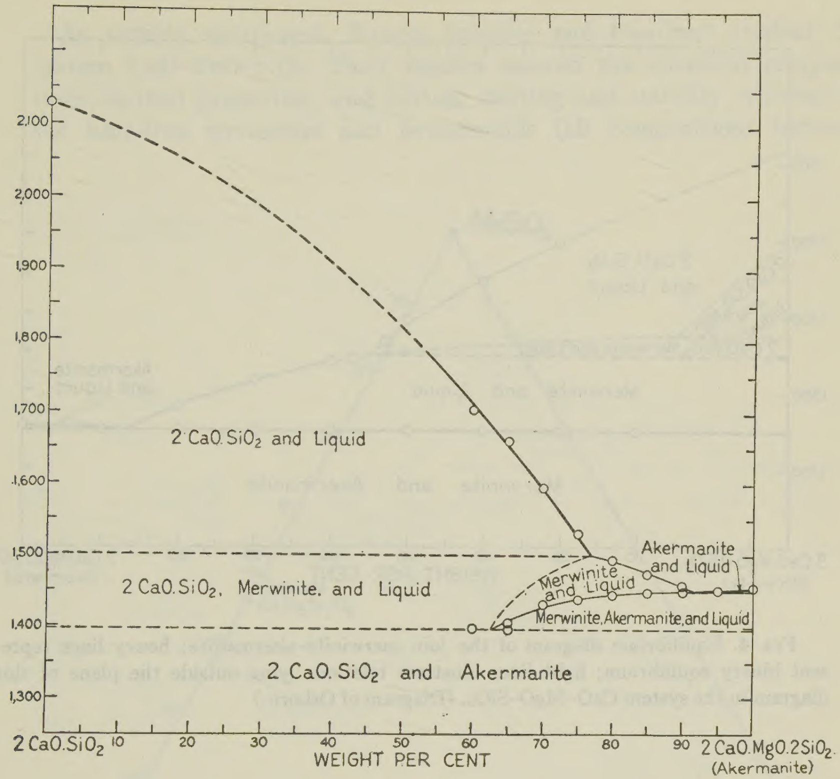

FIG. 3. Equilibrium diagram of the join Ca_2SiO_4–akermanite, heavy lines represent binary equilibrium relations, light lines illustrate relations lying outside the plane of this diagram in the ternary system CaO–MgO–SiO_2. (Diagram of Osborn.)

PYROXENES AND RELATED PYROXENOIDS

The pyroxenes and related pyroxenoids present exceptional complexity both of crystalline modifications and chemical composition. They are a series of polycomponent solid solutions, some of the molecules of which are completely miscible and others only partly so. The important mineral molecules which enter into the composition of the rock-forming pyroxenes are given in Table 1.

The three most important molecules are the metasilicate molecules $CaSiO_3$, $MgSiO_3$ and $FeSiO_3$. The composition triangle, which is given as Fig. 5, shows the chemical relations between diopside and hedenbergite and the simple metasilicates.

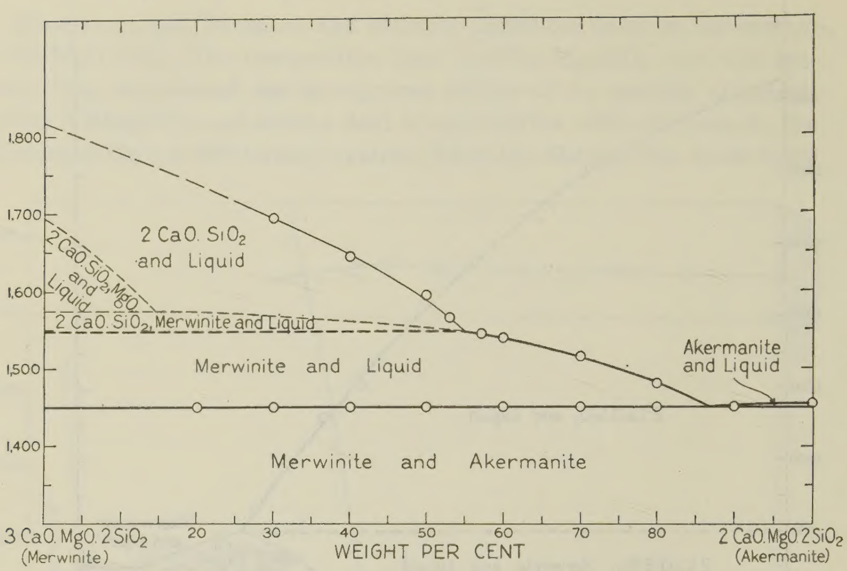

FIG. 4. Equilibrium diagram of the join merwinite–akermanite; heavy lines represent binary equilibrium; light lines illustrate relations lying outside the plane of this diagram in the system $CaO–MgO–SiO_2$. (Diagram of Osborn.)

TABLE 1. MOLECULES OF THE ROCK-FORMING PYROXENES

$CaSiO_3$	Wollastonite, pseudowollastonite
$MgSiO_3$	Enstatite, clinoenstatite
$CaSiO_3 \cdot MgSiO_3$	Diopside
$FeSiO_3$	Ferrosilite, clinoferrosilite
$CaSiO_3 \cdot FeSiO_3$	Hedenbergite
$MnSiO_3$	Rhodonite, bustamite
$CaSiO_3 \cdot MnSiO_3$	Johannsenite
Molecules containing	
Al_2O_3	Augites
Fe_2O_3	Augites and babingtonite
TiO_2	Titaniferous augites
$Na_2O \cdot Al_2O_3 \cdot 4SiO_2$	Jadeite
$Na_2O \cdot Fe_2O_3 \cdot 4SiO_2$	Acmite, aegirite

As already mentioned, Bowen, Schairer and Posnjak[2b] studied the system CaO–FeO–SiO_2. Their studies showed the chemical compositions, optical properties, and mutual melting and stability relations of the lime-iron pyroxenes and pyroxenoids (all compositions between $CaSiO_3$ and $FeSiO_3$), including pseudowollastonite (α–$CaSiO_3$), wollastonite (β–$CaSiO_3$ solid solutions with up to 76 per cent $FeSiO_3$), hedenbergite (with hedenbergite solid solutions containing up to 80 per cent $FeSiO_3$), and the lime-iron olivines. Their diagram for the join $CaSiO_3$–$FeSiO_3$ is given here as Fig. 6.

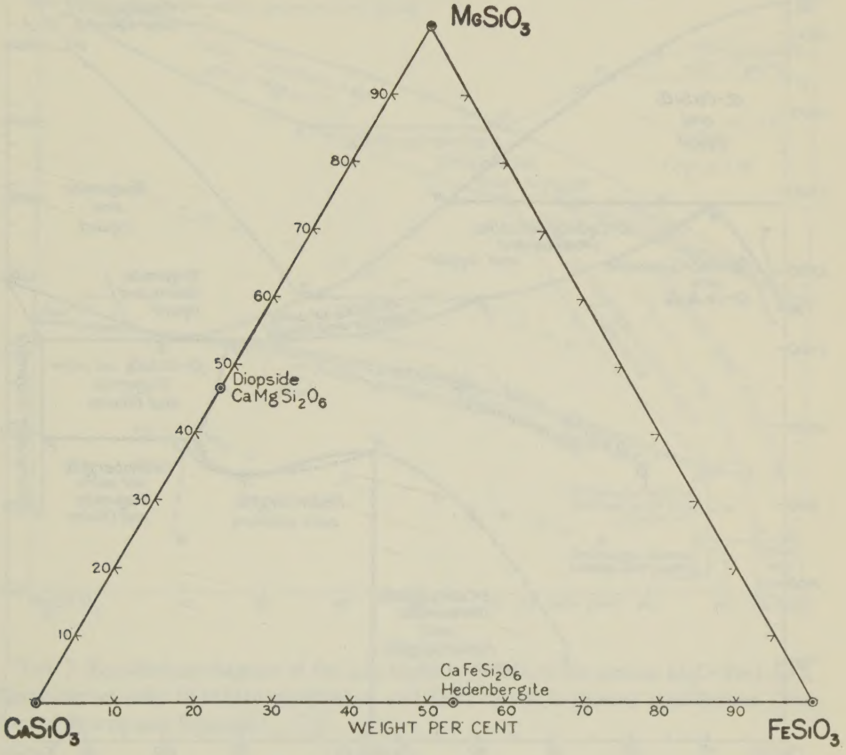

FIG. 5. Composition triangle $CaSiO_3$–$MgSiO_3$–$FeSiO_3$ showing the chemical relations between diopside, hedenbergite, and the three simple metasilicates.

In like manner, in their study of the system MgO–FeO–SiO_2, Bowen and Schairer[1] presented complete data on chemical compositions, optical properties, and mutual melting and stability relations of the $MgSiO_3$–

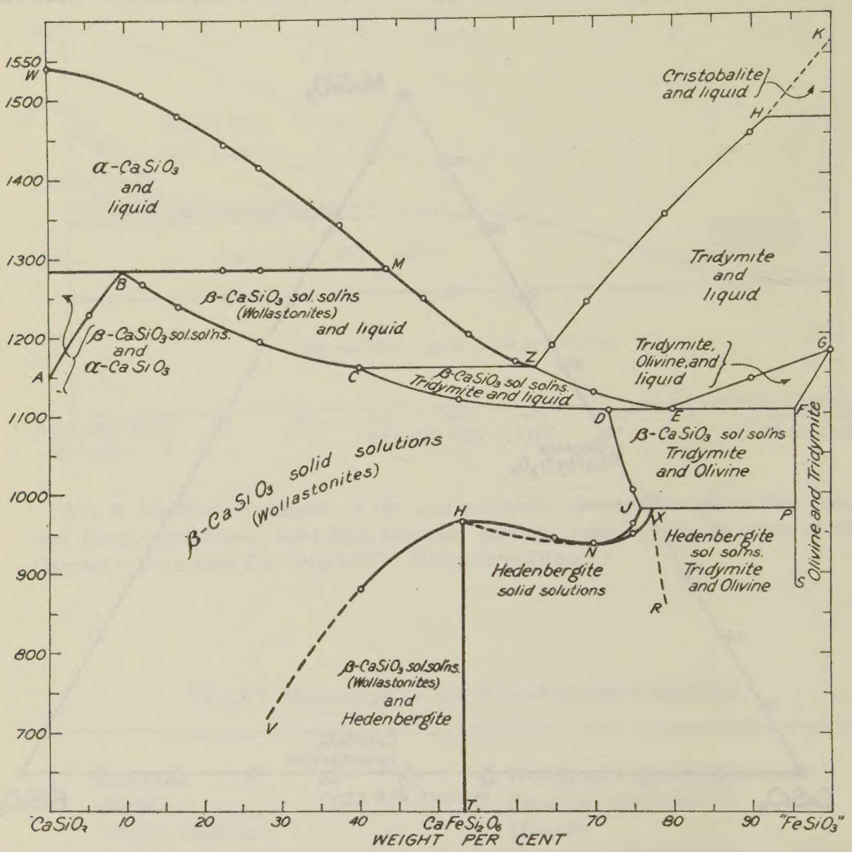

FIG. 6. Equilibrium diagram of the join $CaSiO_3$–$FeSiO_3$ in the system CaO–FeO–SiO_2. Heavy curves refer to binary equilibrium and light curves to ternary equilibrium. (Diagram of Bowen, Schairer and Posnjak.)

$FeSiO_3$ pyroxenes, including both the clino-pyroxenes and the ortho-pyroxenes, and their relations to the magnesia-iron olivines. Their diagram for the join $MgSiO_3$–$FeSiO_3$ is reproduced here as Fig. 7.

Bowen,[5] in his study of the system diopside–forsterite–silica, showed the presence of a complete series of solid solutions between diopside and clinoenstatite and gave their optical properties and complete melting relations. His equilibrium diagram is reproduced here as Fig. 8.

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[5] Bowen, N. L., The ternary system: diopside–forsterite–silica: *Am. Jour. Sci.*, **38**, 207–264 (1914).

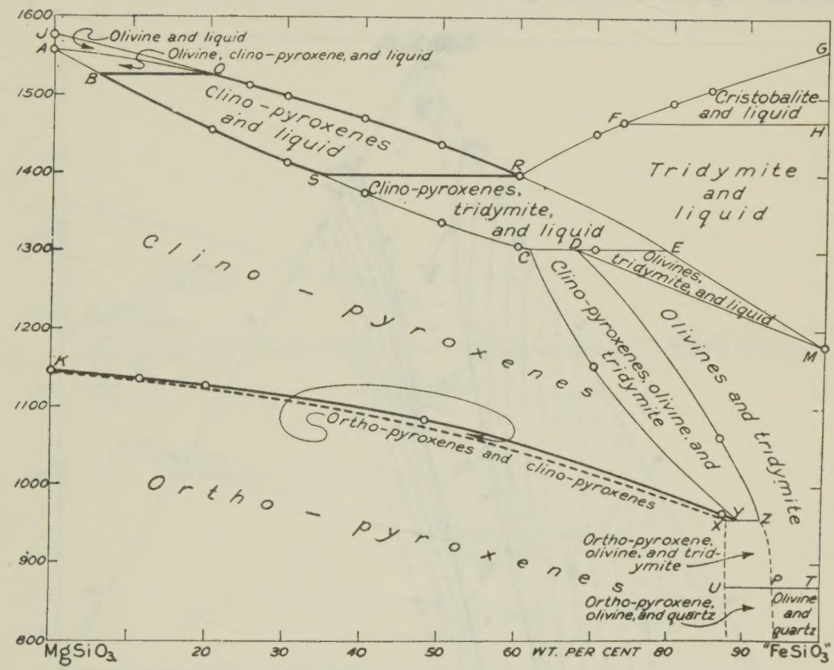

FIG. 7. Equilibrium diagram of the join $MgSiO_3$–$FeSiO_3$ in the system MgO–FeO–SiO_2 Heavy curves refer to binary equilibrium and light curves to ternary equilibrium. (Diagram of Bowen and Schairer.)

Recently, Schairer and Bowen[6] showed that in the system $CaSiO_3$–diopside there is little or no solid solution of diopside in pseudowollastonite (α–$CaSiO_3$) or of $CaSiO_3$ in diopside, but that wollastonite (β–$CaSiO_3$) may take up to a maximum of 22 per cent of diopside in solid solution. Their equilibrium diagram is reproduced here as Fig. 9.

Bowen and Schairer[7] showed that acmite ($Na_2O \cdot Fe_2O_3 \cdot 4SiO_2$) melts incongruently at 990°C. to hematite and liquid. In a later paper, Bowen, Schairer and Willems[8] described the melting relations of acmite in the presence of an excess of any of its component oxides. Their equilibrium diagram is given here as Fig. 10.

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[6] Schairer, J. F., and Bowen, N. L., The binary system $CaSiO_3$–diopside and the relations between $CaSiO_3$ and akermanite: *Am. Jour. Sci.*, **240**, 725–742 (1935).

[7] Bowen, N. L., and Schairer, J. F., The fusion relations of acmite: *Am. Jour. Sci.*, **18**, 365–374 (1929).

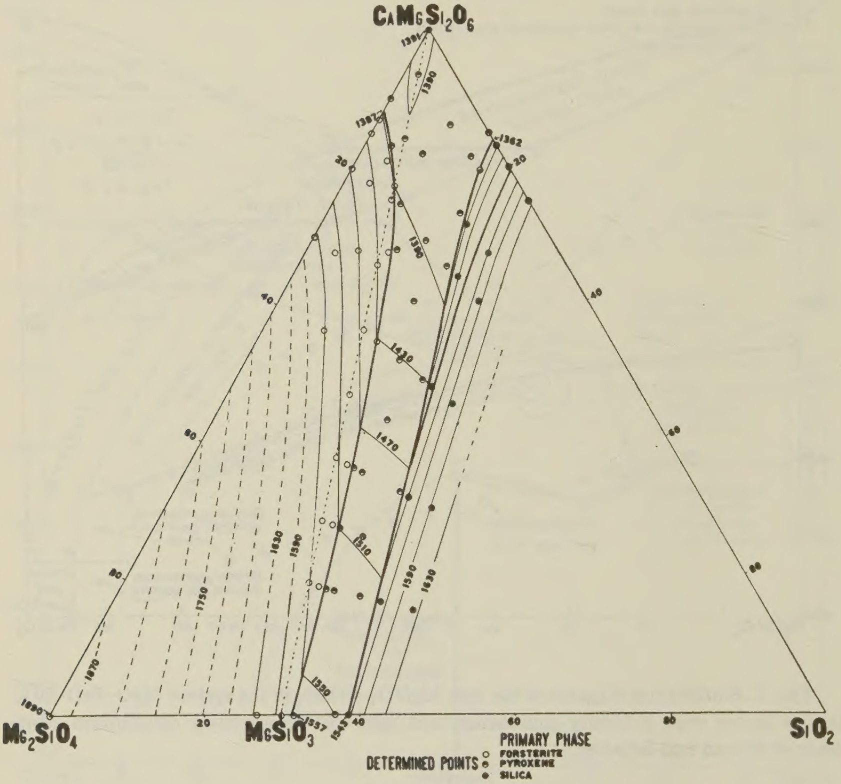

FIG. 8. Equilibrium diagram of the ternary system forsterite–diopside–silica showing the melting relations of pyroxenes between diopside and clinoenstatite ($MgSiO_3$). (Diagram of Bowen.)

Greig and Barth[9] in studies of the system nepheline–albite, and Schairer and Bowen in unpublished studies of the system Na_2O–Al_2O_3–SiO_2, found that there was no field of jadeite on the liquidus surface and that no crystals of jadeite ($Na_2O \cdot Al_2O_3 \cdot 4SiO_2$) appeared at any of the temperatures studied. A crystallized charge of the composition $Na_2O \cdot Al_2O_3 \cdot 4SiO_2$ consisted of crystals of nepheline and albite. Jadeite might be a stable phase only at low temperatures or at pressures above atmospheric pressure or it might only be stable in solid solution with other pyroxene molecules. More experimental work is necessary.

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[8] Bowen, N. L., Schairer, J. F., and Willems, H. W. V., The ternary system Na_2SiO_3–Fe_2O_3–SiO_2: *Am. Jour. Sci.*, **20**, 405–455 (1930).

[9] Greig, J. W., and Barth, T. F. W., The system, $Na_2O \cdot Al_2O_3 \cdot 2SiO_2$ (nephelite, carnegieite)–$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$ (albite): *Am. Jour. Sci.*, **35-A**, 93–112 (1938).

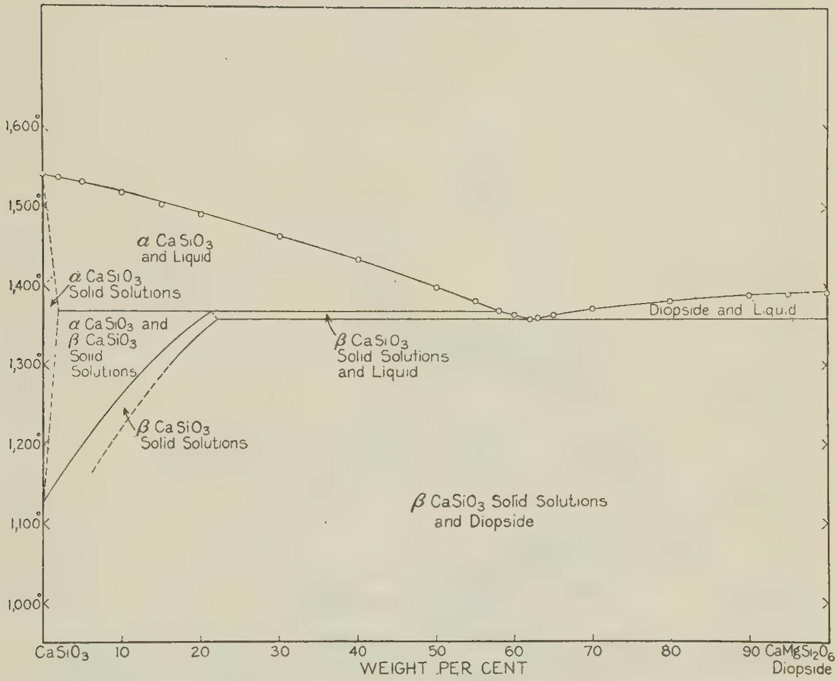

FIG. 9. Equilibrium diagram of the binary system $CaSiO_3$ (wollastonite, pseudowollastonite)–$CaMgSi_2O_6$ (diopside). (Diagram of Schairer and Bowen.)

Recently, Schairer[10] presented an equilibrium diagram showing the liquidus relations in the system $FeO–Al_2O_3–SiO_2$. No compound of FeO, Al_2O_3 and SiO_2 was encountered which might enter into solid solution with other pyroxene or pyroxenoid molecules in the aluminous pyroxenes. Experiments at sub-liquidus temperatures are not yet completed. In this same paper, the results of quenching experiments on five joins through the tetrahedron representing the quaternary system $CaO–FeO–Al_2O_3–SiO_2$ were presented. The mutual melting relations between olivines, pyroxenoids and melilites whose compositions lie in this system were given. Exact data on the chemical composition of the several solid phases of variable composition (solid solutions) have not yet been obtained.

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[10] Schairer, J. F., The system $CaO–FeO–Al_2O_3–SiO_2$: I, Results of quenching experiments on five joins. *Jour. Am. Ceram. Soc.*, **25**, 241–274 (1942); see page 245.

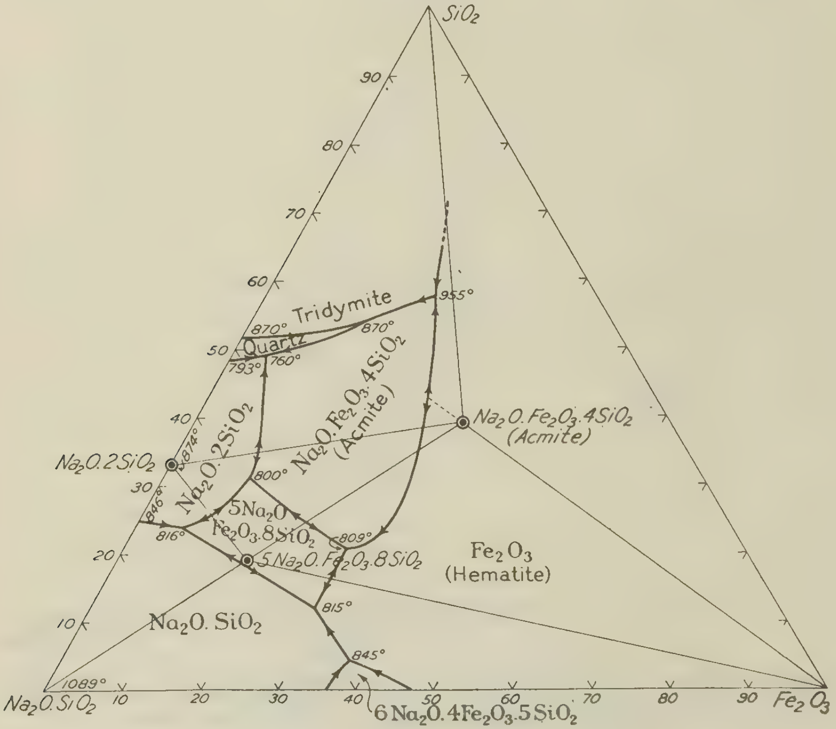

FIG. 10. Equilibrium diagram of $Na_2SiO_3–Fe_2O_3–SiO_2$, a portion of the ternary system $Na_2O–Fe_2O_3–SiO_2$ without isotherms but showing the fields of stability and the incongruent nature of the melting of the pyroxene, acmite. (Diagram of Bowen, Schairer and Willems.)

MELILITES

The melilites are complex solid solutions of several different molecules which are wholly or partially miscible in the solid state and form well crystallized tetragonal crystals. From studies of the analyses of melilite it has been shown that akermanite ($2CaO \cdot MgO \cdot 2SiO_2$) and gehlenite ($2CaO \cdot Al_2O_3 \cdot SiO_2$) are the dominant molecules.

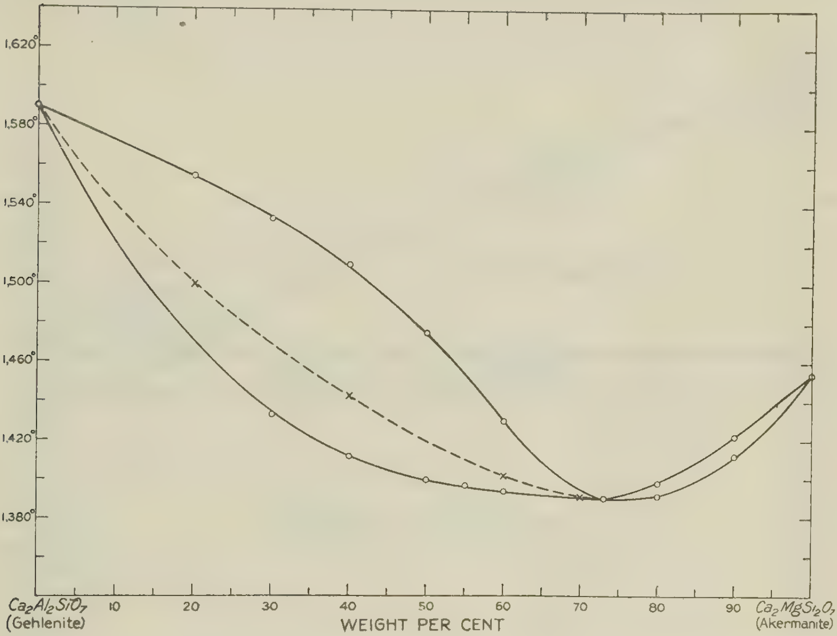

FIG. 11. Equilibrium diagram of the binary system gehlenite–akermanite. Dashed line is solidus curve of Ferguson and Buddington. (Diagram of Osborn and Schairer.)

Ferguson and Buddington[11] showed that akermanite and gehlenite form a complete series of solid solutions with a temperature minimum on the liquidus surface. They recorded the optical properties of these solid solutions. Further optical and thermal data were given by Buddington[12] on more complex artificial melilite solid solutions. Recently, Osborn and Schairer[13] corrected the position of the solidus curve for the system akermanite–gehlenite. Their diagram is given here as Fig. 11.

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[11] Ferguson, J. B., and Buddington, A. F., The binary system åkermanite–gehlenite: *Am. Jour. Sci.*, **50**, 131–140 (1920).

[12] Buddington, A. F., On some natural and synthetic melilites: *Am. Jour. Sci.*, **3**, 35–87 (1922).

[13] Osborn, E. F., and Schairer, J. F., The ternary system pseudowollastonite–akermanite–gehlenite: *Am. Jour. Sci.*, **239**, 715–763 (1941).

Bowen, Schairer and Posnjak[14] described the iron analogue of akermanite, $2CaO \cdot FeO \cdot 2SiO_2$, and gave its optical properties. This compound is stable only below 775°C. and above this temperature breaks up into a pyroxenoid, wollastonite (β–$CaSiO_3$) and an olivine, Fe-monticellite ($CaFeSiO_4$). Their diagram for $CaSiO_3$–$CaFeSiO_4$ is reproduced here as Fig. 12. They also call attention to the fact that in attempts to prepare crystalline akermanite from a glass of that composition, a single phase, akermanite was obtained at 1375°C. while this same glass crystallized at 1050°C. gave a crystal complex with Ca_2SiO_4 as one of the phases.

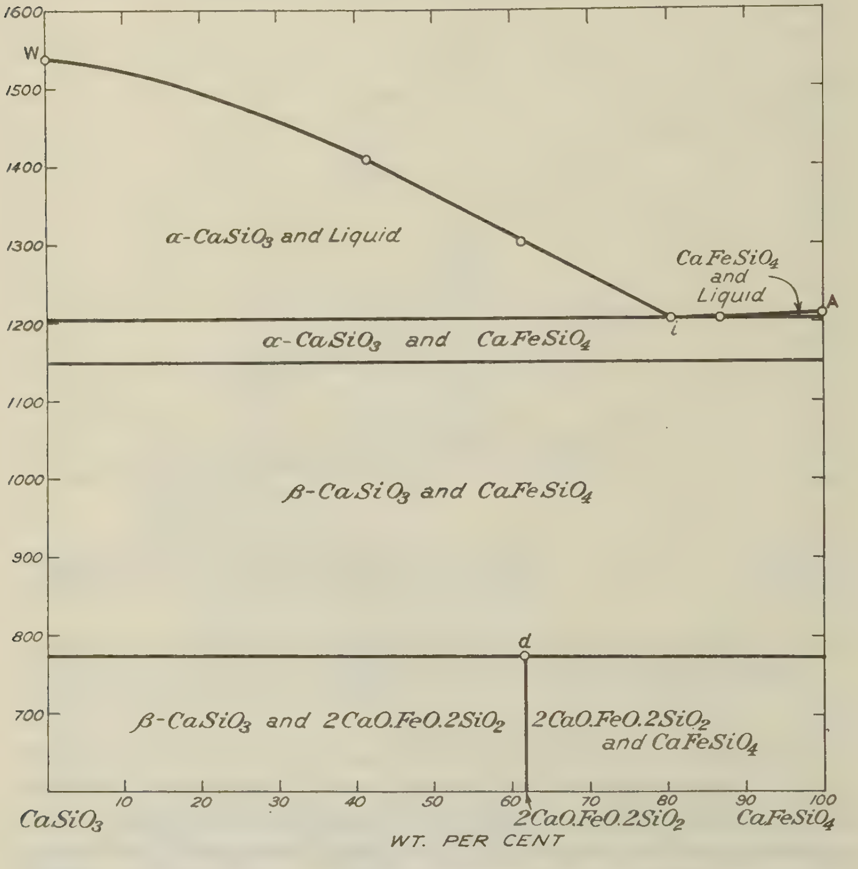

FIG. 12. Equilibrium diagram of the binary system $CaSiO_3$–$CaFeSiO_4$ showing stability relations of the melilite, Fe-akermanite. (Diagram of Bowen, Schairer and Posnjak.)

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[14] See ref. 2*b*, pp. 211 and 276.

Recently, Osborn and Schairer[15] observed by heating pure artificial akermanite crystals that they remain homogeneous above 1325°C., but at temperatures below 1325°C., very small euhedral crystals (not positively identified) grow within the akermanite crystals. Investigation of the stability relations of akermanite and related compositions is continuing.

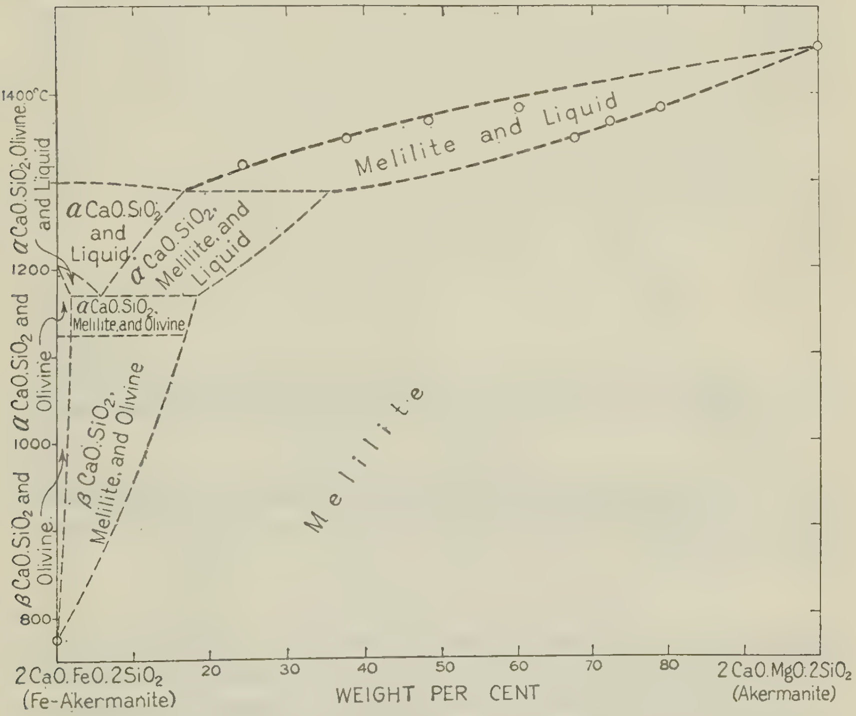

FIG. 13. Preliminary equilibrium diagram of the join Fe-akermanite–akermanite; a portion of the join $CaSiO_3$–MgO–FeO in the quaternary system CaO–MgO–FeO–SiO_2. (Unpublished diagram of Schairer and Osborn.)

As a part of the study of the quaternary system CaO–MgO–FeO–SiO_2 now in progress, Schairer and Osborn[16] have obtained some data for the join $CaSiO_3$–MgO–FeO. The line akermanite–Fe-akermanite lies in this join. The preliminary data for this line, which have not yet been published, are reproduced here as Figs. 13 and 14, with the kind permission of Dr. E. F. Osborn.

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[15] Osborn, E. F., and Schairer, J. F., The ternary system pseudowollastonite–akermanite–gehlenite: *Am. Jour. Sci.*, **239**, 715–763 (1941); see page 718.

[16] These preliminary data were presented by J. F. Schairer and E. F. Osborn at the 44th Annual Meeting of the American Ceramic Society April 22, 1942, at Cincinnati, Ohio, in order to make the information immediately available while progress on the investigation was temporarily interrupted by other work.

The complex crystallization relations in the system $CaSiO_3$–akermanite–gehlenite, which combines simple melilites and a pyroxenoid are given by Osborn and Schairer.[17] There is no ternary eutectic. The lowest temperature at which liquid is present is at the ternary minimum (1302°C.) on the boundary curve between the fields of melilite and α–$CaSiO_3$. It is shown that zoned solid solution crystals possessing one or more reversals in the direction of zoning (oscillatory zoning) may be produced by normal processes of crystallization with continuously decreasing temperature.

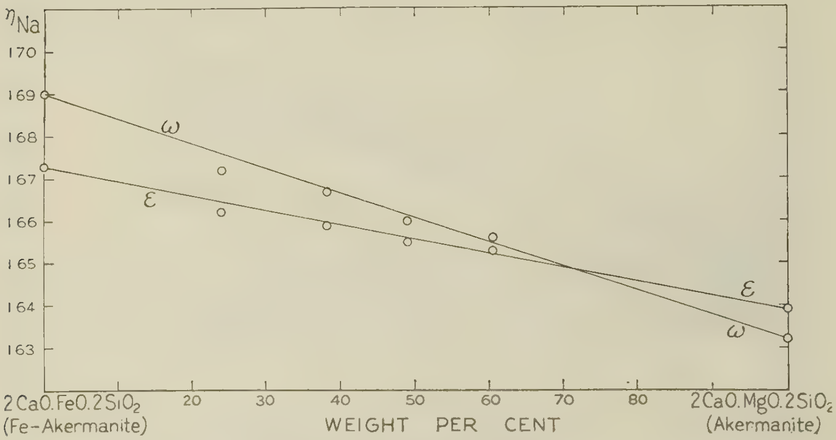

FIG. 14. Diagram showing indices of refraction of artificial melilites lying between Fe-akermanite and akermanite in chemical composition. (Unpublished diagram of Schairer and Osborn.)

CONCLUDING REMARKS

The foregoing brief discussion is perhaps sufficient to indicate that substantial progress has been made on determining the exact chemical compositions and range of compositions and the temperature stability relations of the various rock-forming olivines, pyroxenes (and related pyroxenoids), and melilites. Some progress has been made on determination of the mutual melting relations of these groups of minerals and of these minerals with other rock-forming species. More progress on both aspects of the problem may be expected from studies of four quaternary systems now in progress: $CaO–FeO–Al_2O_3–SiO_2$, $CaO–MgO–Al_2O_3–SiO_2$ and $CaO–MgO–FeO–SiO_2$ at the Geophysical Laboratory, and $CaO–Na_2O–Al_2O_3–SiO_2$ by Bowen and his students at the University of Chicago.

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[17] Osborn, E. F., and Schairer, J. F., The ternary system pseudowollastonite–akermanite–gehlenite: *Am. Jour. Sci.*, **239**, 715–763 (1941).

WEINSCHENKITE, YTTRIUM PHOSPHATE DIHYDRATE, FROM VIRGINIA*

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ABSTRACT

Weinschenkite, $YPO_4 \cdot 2H_2O$, hitherto known only from a single Bavarian locality, occurs in Rockbridge County, Virginia, where as in Bavaria it encrusts manganiferous limonite. This paper describes the occurrence of the mineral, gives its physical properties and chemical composition, with special attention to the spectroscopy of the rare earths present, and discusses the fluorescence, dehydration, and laboratory synthesis of the compound. It is suggested that a combination of biochemical processes involving forest growth and geochemical reactions of a diagenetic nature in the upper soil zone are the main factors that have resulted in the formation of weinschenkite.

OCCURRENCE OF WEINSCHENKITE IN VIRGINIA

The Kelly Bank mine, where the weinschenkite occurs, comprises three small open pits at the west foot of the Blue Ridge, a mile east of the village of Vesuvius, Rockbridge County, Virginia. The mine was originally worked for limonite, but was briefly re-opened for manganiferous iron ore in 1940. The ore occurs mostly as large irregular lumps having botryoidal surfaces and embedded in yellow clay containing lenses and nodules of chert and silicified calcareous oölite. The clay occupies the stratigraphic position of the Tomstown dolomite (lower Cambrian) close to its contact with the underlying Antietam sandstone, which in this vicinity dips steeply northward. The clay with the contained ore (Fig. 1) was formed during or since early Tertiary time by weathering of the Tomstown beds beneath the valley-floor peneplain. In its relations to geologic structure, rock strata, and topography, the

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Kelly Bank mine does not differ in any obvious respect from the numerous other occurrences of iron and manganese ore that have been described in the Blue Ridge region.[1]

In the course of an examination of manganese ore deposits of the Virginia Blue Ridge country during 1941, H. D. Miser and M. M. Knechtel observed that specimens of manganiferous iron oxide from the

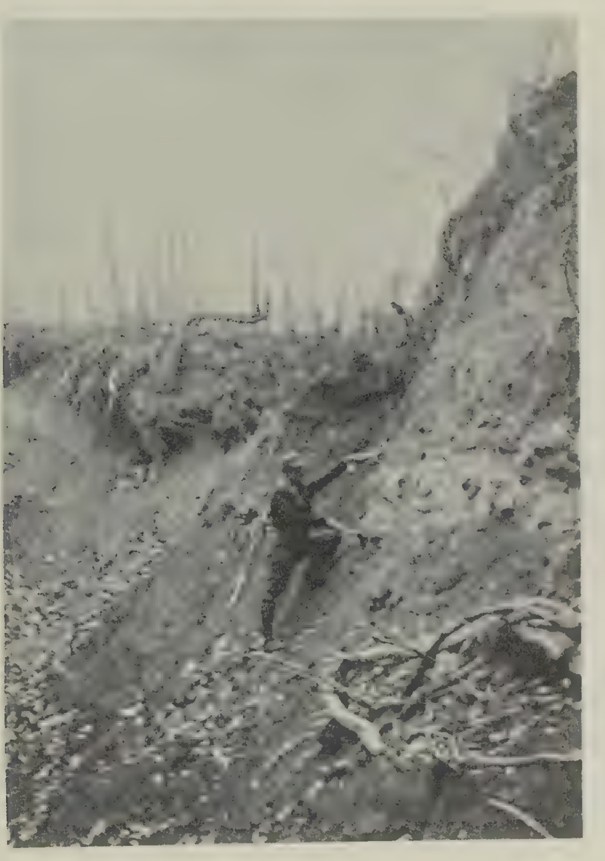

FIG. 1. View of Kelly Bank mine, Vesuvius, Virginia. The weinschenkite is restricted to a zone a meter thick and several meters wide, shown between the two picks.

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[1] Harder, E. C., The iron ores of the Appalachian region in Virginia: *U. S. Geol. Survey, Bull.* **380,** 235–237 (1909).

Stose, G. W., Miser, H. D., Katz, F. J., Hewett, D. F., Manganese deposits of the west foot of the Blue Ridge, Virginia: *Virginia Geol. Survey, Bull.* **17** (1919).

Knechtel, M. M., Manganese deposits of the Lyndhurst-Vesuvius district: *U. S. Geol. Survey, Bull.* **940.**

Kelly Bank mine were more or less coated with minute specks of a whitish material. Under a hand lens the specks were resolved into radially fibrous aggregates, the largest less than a millimeter across; the fibers themselves were white with a silky luster. The material proved to be the rare mineral weinschenkite, $YPO_4 \cdot 2H_2O$, hitherto known only from one occurrence, the Nitzelbuch mine in Auerbach, Bavaria, described by H. Laubmann[2] in 1923.

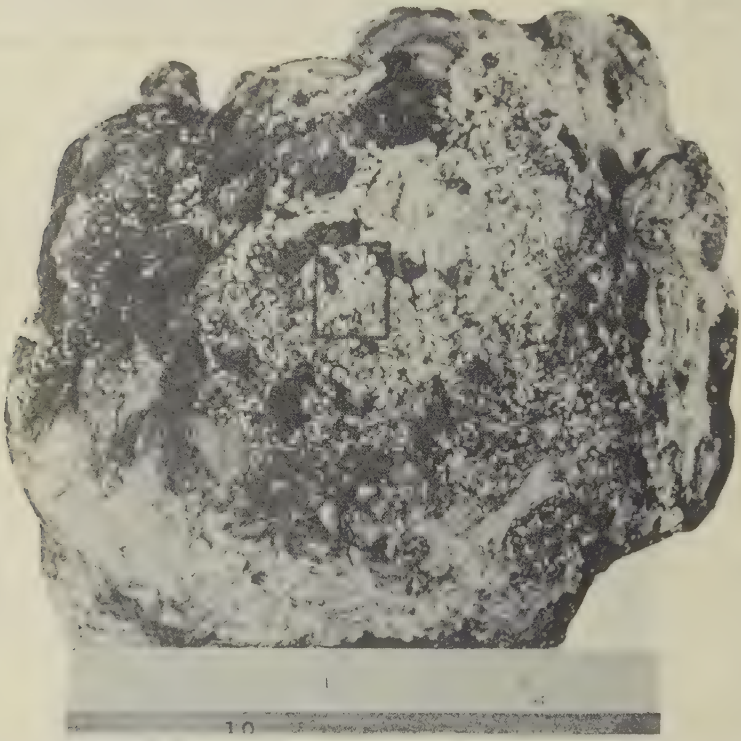

Fig. 2. Manganiferous limonite from Kelly Bank mine, Vesuvius, Virginia, showing specks of weinschenkite on surface of ore. Scale in inches.

The appearance of the mineral characteristically coating brown siliceous limonite, or black manganese oxide, is shown in Fig. 2. The indicated rectangular area, enlarged 12 diameters, is shown in Fig. 2. The hemispherical rosettes frequently have a dusty brownish surface;

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[2] Die Phosphatmineralien und Edelerden des Amberg-Auerbacher Erzkörpers: *Geognostische Jahreshefte* **53**, 193–204, Munich (1923).

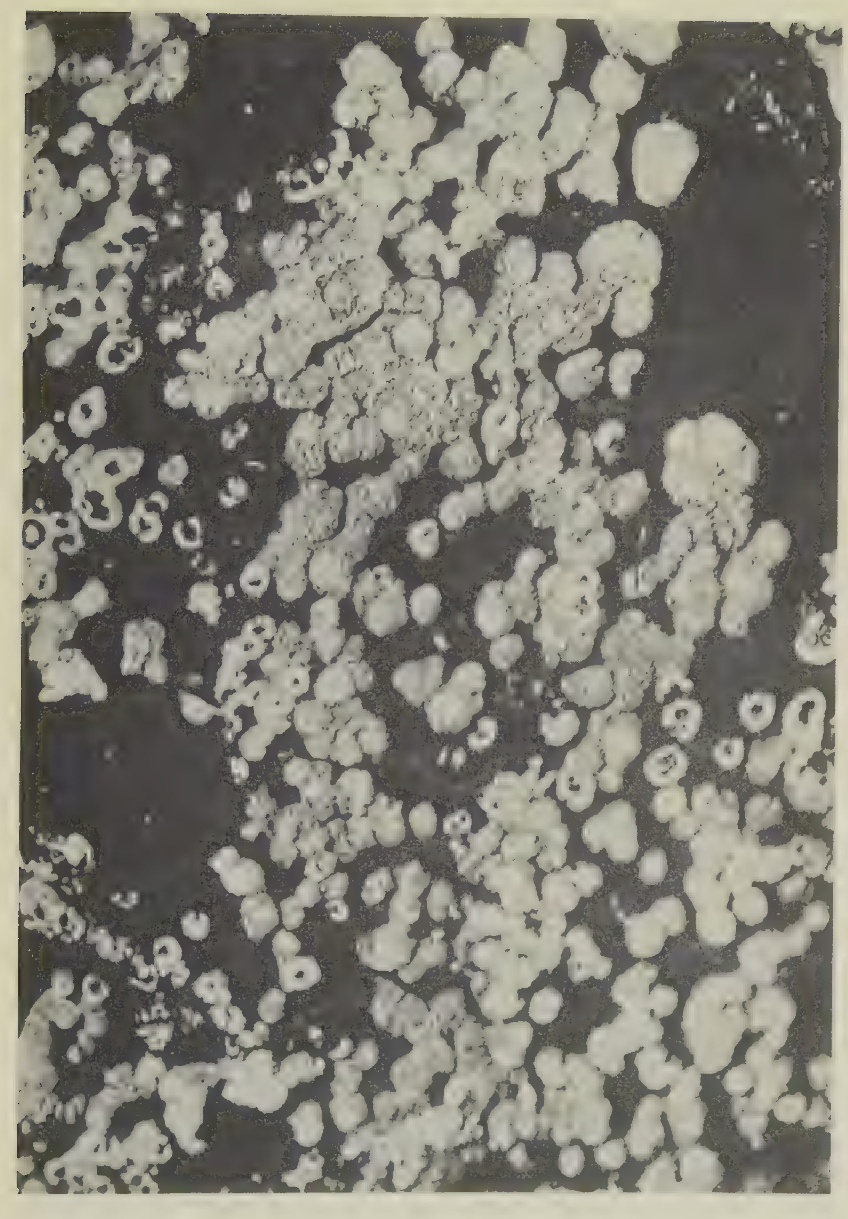

FIG. 3. The rectangular area in Fig. 1 is magnified 12 times and shows an area ½ by ⅜ of an inch. The spherulites showing radially fibrous structure are clearly seen, also the black cores and spherical shells of manganese oxide. The grey dusty exterior contrasts with the clean white interior, shown where the spherulites have been broken.

many of them, when broken, show concentric black zones or cores of manganese dioxide. In some of them the black oxide forms a ridge enveloping the lower part of a rosette; these features indicate overlapping of the weinschenkite and the last of the manganese dioxide deposition.

PROPERTIES OF WEINSCHENKITE

This rare mineral was identified by qualitative chemical tests, optical properties, spectrographic analysis, and comparison of the *x*-ray diffraction pattern with that of the original weinschenkite from the type Bavarian locality (Nat. Mus. No. C-4350) kindly furnished by Dr. W. F. Foshag of the United States National Museum. In all instances the observed properties for the Virginian and Bavarian minerals were in substantial agreement.

Optical Properties

For the Bavarian mineral there are two sets of optical data, one by Laubmann, given in the original paper, and a second set in Larsen-Berman,[3] presumably determined by Larsen and Berman; the present writers' data agree better with the latter.

The optical data are as follows:

Weinschenkite from Bavaria		*Weinschenkite from Virginia*
Laubmann	*Larsen-Berman*	*Milton-Murata-Knechtel*
$\alpha=1.58$	1.600	1.605
β	1.608	1.612
$\gamma=1.63$	1.645	1.645
$X=b$, $Z:c=30°\pm$;	$X=b$, $Z:c=30°\pm$	$X=b$, $Z:c=35°\pm$
Mono. laths$\parallel$010 elong.$\parallel c$		Fibers or laths$\parallel c$
Dispersion "normal"		Marked dispersion of bisectrices.

Laubmann calls attention to the difficulty of making precise optical determinations because of the minute dimensions of the particles, other than length along *c*. His remarks on this point are justified, and it was found necessary to view the laths immersed in oil under high magnification to obtain a definite image of the terminations of the laths, so that α and β could be measured. Even so, the very definite dispersion of the bisectrices introduced further difficulties in determining at which position the refractive index of the oil matched that of the grain (using white light). Consequently, the figures cited must be considered as uncertain in the third decimal, but exact enough for the purpose of identifying the mineral.

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[3] *U. S. Geol. Surv., Bull.* **848,** Microscopic Determination of the Non-opaque Minerals Washington (1934).

X-Ray Diffraction Pattern

The *x*-ray powder patterns of weinschenkite are shown in Figs. 4(*a*), (*b*) and (*c*). Measurements on the photographs show that the cell volumes of the two natural minerals differ by less than 0.2% and the cell volume of the artificial mineral which gives a more diffuse pattern is smaller than that of either natural mineral by less than 0.6%. Since the uncertainty in density determinations is greater than these variations, calculated densities are based on Strunz's values of the cell constants.

POWDER PATTERN DATA

Weinschenkite (*Virginia*)		*Gypsum*	
Spacing	Intensity	Spacing	Intensity
7.51	vvs	7.7	0.50
4.18	vvs	4.29	1.0
3.74	m	3.81	0.15
3.01	vvs	3.06	0.63
2.82	m	2.87	0.63
2.60	mw	2.68	0.50
2.39	mw	2.48	0.20
2.164	ms	2.22	0.20
2.042	mw	2.07	0.50
1.965	mw		
1.855	mw	1.88	0.25
1.825	mw		
1.774	s		
1.755	m		
1.638	mw		
1.594	mw		
1.530	w		
1.503	w		
1.438	mw		
1.344	w		
1.248	w		
1.214	w		
1.124	mw		
1.118	s		
1.045	w (b)		
0.999	vw (b)		

The weinschenkite pattern was made with iron radiation, and the weaker lines are omitted. The data for gypsum are from the *ASTM-NRC* card file.

(b) indicates a broad line.

Cell Constants and Density

Strunz,[4] studying the Bavarian mineral whose composition is given

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[4] Strunz, H, Isotypy between $YPO_4 \cdot 2H_2O$ and $CaSO_4 \cdot 2H_2O$. Abstract in *Chemical Abstracts*, **36,** 2813 (1942).

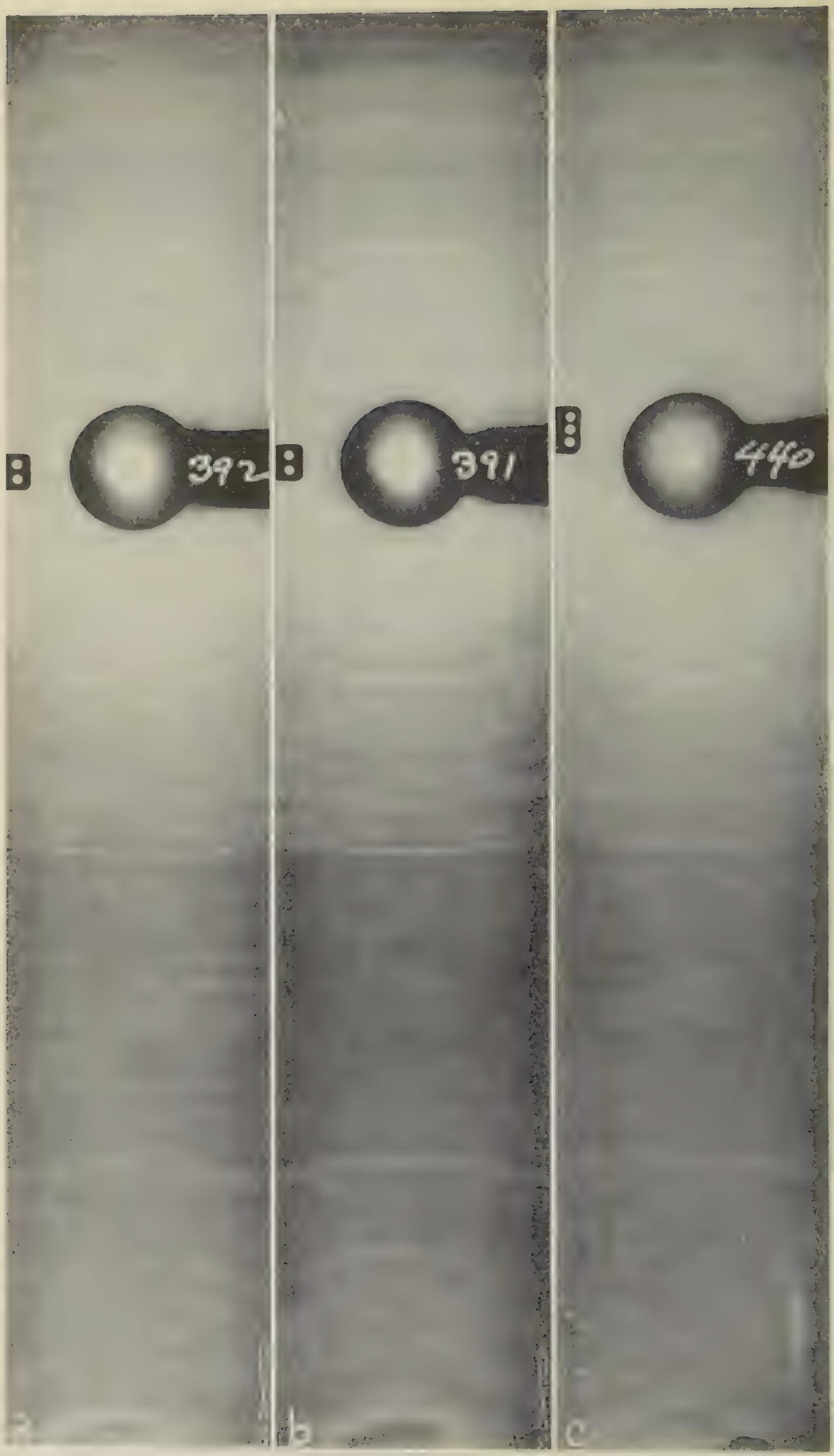

FIG. 4. *X*-ray diffraction patterns. (a) Weinschenkite, Auerbach, Bavaria, (b) Weinschenkite from Vesuvius, Virginia, (c) Synthetic $YPO_4 \cdot 2H_2O$ (artificial weinschenkite).

as $(Y, Er)PO_4 \cdot 2H_2O$, found the lattice constants (powder and rotation diagrams around (001) and goniometric measurements) to be:

$a = 6.48$ Å $\quad b = 15.12$ Å $\quad c = 6.28$ Å
$a:b:c = 0.429:1:0.415 \quad \beta = 129°24'$
space group $C^6_{2\gamma} - A\ 2/a$ (?) $\quad Z = 4$ mols. per unit cell,
cleavage angle $(\bar{1}01)/(001) = 60°30' \pm 30'$. Density determined $= 3.10$.

These data of Strunz's, together with the value of the mean atomic weight of the mixed rare earth metals (100.05) of the Bavarian mineral determined by Henrich,[5] may be used to calculate the density of the Bavarian weinschenkite. The density

$$D = \frac{\text{mass of unit cell}}{\text{volume of unit cell}} = \frac{\dfrac{\text{4 Molecular weights}}{\text{Avogadro's Number}}}{a\ b\ c\ \sin\beta}$$

where $a = 6.48$ Å, $b = 15.12$ Å, $c = 6.28$ Å,
$\beta = 129°24'$, $\sin\beta = 0.772734$
whence $a\ b\ c\ \sin\beta = 475.5$ Å^3.

Using chemical atomic mass units and assuming that Strunz's values are based on the "crystal Ångstrom" scale,

N (Avogadro's Number) $= (6.0596 \pm 0.0016) \times 10^{23}$ [6] and

$$D = \frac{4M}{6.0596 \times 10^{23} \times 475.5 \times 10^{-24}} = 0.01388_4\ M$$

for $M_{RPO_4 \cdot 2H_2O} = 231.06$

$$D_{\text{Bavarian weinschenkite}} = 3.208.$$

The mean atomic weight of the rare earth elements of the Virginia mineral was determined (by weighing the anhydrous sulphate derived from a weighed quantity of oxide) to be 104.5. For the Virginia mineral, therefore, $M_{RPO_4 . 2H_2O} = 235.5$, and the density of the Virginia weinschenkite is calculated as 3.270. Actual determination by floating in a methylene iodide-acetone mixture and weighing the matched liquid in a pycnometer gave 3.263. Finally, a similar determination made on synthetic weinschenkite gave 3.17. These several values for the density, with some other computed results, are tabulated in Table 1.

The determined and calculated values for the Virginia mineral are in reasonable agreement and indicate approximately four times as much yttrium phosphate as the heavier rare-earth phosphates (ytterbium, erbium, etc.). The discrepancy in the values for the synthetic material

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[5] Henrich, F., *Jour. prakt. Chemie*, **142**, 1–5 (1935).

[6] This value is obtained from a recent paper by J. A. Bearden, Evaluation of the Avogadro number, N, and the charge on the electron, 3, by x-rays: *Jour. Applied Physics*, **12** (395–403), May (1941).

For a discussion by W. Schlecht of Avogadro's number in reference to crystallographic calculations, see page 108 of this issue.

TABLE 1. DETERMINED AND CALCULATED DENSITY OF WEINSCHENKITE AND OTHER RARE-EARTH PHOSPHATES

	Determined	*Calculated*
Bavarian	3.10 (Strunz)	3.208
Virginian	3.263	3.270
Synthetic	3.17	—
Pure $YPO_4 \cdot 2H_2O$	—	3.05
$CdPO_4 \cdot 2H_2O$, $DyPO_4 \cdot 2H_2O$, $ErPO_4 \cdot 2H_2O$, $YbPO_4 \cdot 2H_2O$	—	4.04–4.23

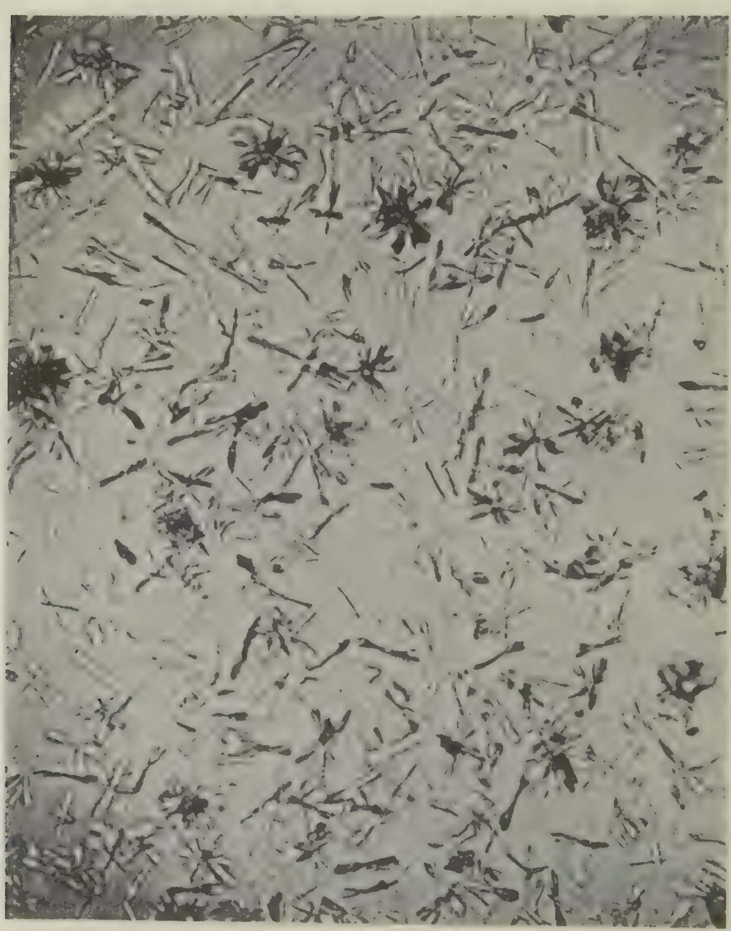

FIG. 5. Synthetic weinschenkite, $YPO_4 \cdot 2H_2O$. Note tendency to spherulitic development. ×250.

arises from the fact that the yttrium salt used in preparing the compound contained some of the heavier rare-earth elements as is readily seen in its spectrogram. It is possible that Strunz's determination for the Bavarian mineral is somewhat low, the tendency of the felted needles to retain trapped air being a likely source of error.

SYNTHESIS OF WEINSCHENKITE

Some artificial weinschenkite was made from a sample of yttrium nitrate, in the form of pink deliquescent crystals, manufactured by E. deHaën, Hannover, Germany. Solution in water of the nitrate was followed by precipitation with tribasic sodium phosphate, and washing with water to remove the excess precipitant and sodium nitrate from the yttrium phosphate formed. The precipitate was apparently amorphous, probably crystalline, but so fine-grained as to be "statistically isotropic." On standing in water for several weeks, however, the yttrium phosphate crystallized as shown in Fig. 5; and optically, and by *x*-ray examination as shown in Fig. 4, was evidently identical with the natural weinschenkite.

SPECTROGRAPHIC ANALYSIS OF WEINSCHENKITE

Spectrograms of weinschenkite from Virginia and from Bavaria were taken adjacent to each other on the same plate. Carbon electrodes of special purity were used and the spectrograms taken with the Gaertner medium-size quartz spectrograph. The two spectra are practically identical. Strong lines of phosphorus and of the yttrium group elements are present; lines of Fe, Al, Si, Mg, and Ca are very faint; those of Ti, As, Ag, Bi, Cd, Pb, Sb, Sn, Zn, Cu, Ba and Sr, also B, Be, and Ge are absent. The only notable difference between the two spectra is that the lines of ytterbium are stronger for the Virginian weinschenkite. A few faint manganese lines given by the Bavarian mineral are due to impurities, as are the faint lines of Fe, Al, Si, Mg, and Ca mentioned above.

A spectrogram made of the rare earths isolated from the Virginian weinschenkite was examined in detail between the wavelengths 2400–6000 A.U. The rare earth lines were identified by comparison with spectrograms of known rare earth elements on the Dietert projection comparator, and also by determining the wave lengths of the lines and consulting *Harrison's*[7] *Wavelength Tables*, with the following results.

Major elements: Y (predominant), Yb, Er, Dy, Gd.
Minor elements: Nd, Sm, Eu, Ho, Tm, La (trace).
Not found: Th, Sc, Ce, Pr, Tb, Lu.

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[7] Massachusetts Institute of Technology Wavelength Tables compiled under the direction of G. R. Harrison. New York, Wiley & Sons (1939).

F. Henrich[8] has estimated the relative amounts of the rare earths in the Bavarian weinschenkite from the intensity of the L_α x-ray lines as follows:

Y 10, Gd 4, Dy 4, Er 4, Ho 3, Tb and Yb traces and small traces of the cerium earths, mainly neodymium. If the amount of Nd in the cerium earths be taken as 10, then Sm = 4, Eu = 2, Pr = 1. Atomic weight of the mixed earths is 100.05.

The kind and amount of rare earths in the weinschenkite from Virginia and in that from Bavaria are very much the same except for the larger amount of ytterbium in the Virginian mineral. The composition as determined spectrographically for the weinschenkite is interestingly compared with the grouping of the rare earths by Mellor:[9]

			Atomic Number
Cerium family Insoluble K-sulphates		(Thorium Th)	
		(Scandium Sc)	
		Lanthanum La	57
		Cerium Ce	58
		Praseodymium Pr	59
		Neodymium Nd	60
		Samarium Sm	62
Terbium family Moderately soluble K-sulphates		Europium Eu	63
		Gadolinium Gd	64
		Terbium Tb	65
Yttrium family Readily soluble K-sulphates	Erbium sub-family	Dysprosium Dy	66
		Holmium Ho	67
		Erbium Er	68
		Thulium Tm	69
	Ytterbium sub-family	Yttrium Y	39
		Ytterbium Yb	70
		Lutecium Lu	71

Of the cerium family, only a trace of lanthanum and small amounts of neodymium and samarium were found. Gadolinium in moderate amount and europium in small amount represent the terbium family. All of the yttrium family, except lutecium, are present with yttrium by far the most abundant.

Excluding yttrium, the rare earth elements present as major constituents have even atomic numbers, and this relationship, though based on a rough visual estimation of the intensities of spectral lines, is in agreement with what has been found in extensive geochemical studies by Goldschmidt[10] and others, and with the general rule that among the lanthanum series of rare earth elements (atomic numbers 57–71) those with even atomic numbers are more abundant than those with odd atomic numbers.

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[8] Loc. cit.

[9] Mellor, J. W. *Comprehensive Treatise on Inorganic and Theoretical Chemistry*, vol. 5, page 495. London (1924).

Fluorescence and Dehydration Studies

Both weinschenkite and the artificially prepared yttrium phosphate dihydrate do not fluoresce under the mercury vapor lamp provided with the Corning 986 filter. On being gently heated, they both show a moderately strong pink fluorescence, the artificial compound more strongly than the natural mineral. Strongly ignited, both cease to fluoresce.

A dehydration study was made on 0.0912 grams of the air-dried synthetic material; the results are presented in Table 2.

Table 2. Dehydration of Weinschenkite

Temperature °C	Heating Time Hours	Total Loss %	Theoretical Loss %	Fluorescence Color
110	24*	.5	—	none
180	42	12.8	$-1\frac{1}{2}\,H_2O=12.29$	faint pink
180	48	13.5	—	faint pink
250	48	14.6	—	faint pink
345	15	15.3	—	faint pink
450	20	15.9	—	strong pink
900	1	16.8	$-2\,H_2O=16.39$	none

* Reached constant weight.

The water lost at 110° is probably absorbed moisture. The loss of water at the higher temperatures is very slow, the most rapid loss occurring when the sample is first heated to 180°. This relatively rapid loss of twelve per cent of water suggests a dehydration to the hemihydrate, similar to the behavior of gypsum. A faint pink fluorescence appears at this stage and persists as the temperature is raised, until at 450° it becomes markedly enhanced and the sample turns gray. Ignited at 900°, the sample turns white again and becomes non-fluorescent.

The only other study of the fluorescence of yttrium phosphate that has come to our attention comprises some experiments made by Crookes,[11] who tested his material inside of a cathode ray tube. He states:

> "Yttrium phosphate precipitated, washed, and dried at a heat below redness, and introduced into the radiant matter tube. It phosphoresced faintly, giving the citron band hazy

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[10] Goldschmidt, V. M. Geochemische Verteilungsgesetze der Elemente. IX. *Skrift. Norske Vid. Akad. Oslo, I. Mat.-Naturv. Klasse,* **1937**, no. 4. Oslo, 1938.

[11] Crookes, W., *Select Methods in Chemical Analysis*, 3rd ed., page 92. London (**1894**).

and faint, extending from about 3010 to 3060 (frequency squared). The red bands were faint, and the green bands, especially the first one, were stronger than usual. The salt was now removed from the tube aud heated to redness. It became of a grey colour, and now phosphoresced with a beautiful green light. . . . Heating the phosphate before the blowpipe made little change in the character of the phosphorescence."

The difference in the fluorescence behavior of yttrium phosphate as reported by Crookes and found by us may be due to the different methods of excitation used. This seems very probable from the fact that yttrium sulphate is unresponsive to our lamp, whereas Crookes invariably obtained a strong luminescence from it under the action of cathode rays.

Origin of the Weinschenkite

The paragenesis of the Bavarian and Virginian deposits is very similar. The weinschenkite occurs in both as coatings on manganiferous limonite and in neither deposit is there any indication of igneous activity. The mineral was evidently deposited by meteoric waters. Other phosphates, such as wavellite, cacoxenite, apatite, beraunite, dufrenite and pseudowavellite, accompany the weinschenkite in Bavaria, but careful search of the Virginia material has failed to show any other phosphate mineral.

It might be considered that yttrium was an original constituent of the ore-forming solutions and at some later time was extracted and precipitated as the phosphate weinschenkite, in cracks and fissures in the ore. The chemical complexity of many manganese oxide ores, containing cobalt, barium, and lithium, together with the commoner elements, suggests that small quantities of rare earths may be present though overlooked in manganese oxides. Rare earths have not been reported, however, so far as known, in manganese oxides, and so far as known none of the other Appalachian deposits contain weinschenkite or other rare-earth minerals. There is apparently no definite evidence, therefore, to prove or disprove the hypothesis that the yttrium of the weinschenkite is derived from the original manganese oxide by diagenetic processes.

Another possible origin of the weinschenkite, involving cold meteoric waters but a source of the yttrium other than the ore itself, is concentration from the seldom-regarded but almost omnipresent yttrium in soils. Although the quantity of the rare-earth oxides in soils is so little as generally to preclude the formation of rare-earth minerals, it might be that under special conditions, as suggested below, an effective concentration and fixation as a definite mineral species, such as weinschenkite, could be effected. There are many recorded observations on the presence of yttrium and other rare-earth oxides in soils. Part of the rare-earth content is in such more or less common detrital minerals as xenotime, yttrium phosphate, and monazite, a cerium-earth phosphate with minor yttria. Rare earths may also be present as isomorphous replacements of the usual elements in the common minerals of soils. The total rare earth content of the lithosphere is considerable; as, for example, in the Netherlands East Indies Van Tongeren[12] cites the following averages: La_2O_3 0.0023%, Ce_2O_3 0.0029–0.0040%, Nd_2O_3 0.0021–0.0024%, Y_2O_3 group "one or a few thousandths of a percent."

Locally, as in areas of alkalic rocks, there may be as much as ten times these quantities.

Goldschmidt[13] gives 0.0034% as the abundance of yttrium in the earth's crust. The figure for zirconium is 6 times this amount, namely 0.020%, and that for gold, 1/6000 that for yttrium. In other words, there is 6000 times as much yttrium in the earth's crust as the widely distributed gold, and, ubiquitous as the common mineral zircon is, zirconium is only six times as abundant as yttrium.

Although these figures refer to overall percentages and do not necessarily imply a universal distribution, comparable quantities of rare earths may be present generally. In rock and soil analyses, if the rare earths are not specifically sought, they will be counted as alumina. One reason for believing in widespread distribution is the recent work of Robinson, Whetstone and Scribner[14] and others, who have found considerable concentrations of rare earths in tree leaves from various localities in which no deposits of a specific rare-earth mineral are known. For example, Scribner finds in dried hickory leaves from Rockville, Maryland, 0.17% of rare earths; hickory leaves from Amelia, Virginia, a rare-earth mineral locality, have but slightly more, 0.20%. He also cites A. A. Drobkov[15] to the effect that phosphorites may contain as much as 0.8% of rare earths.

An examination was made of fallen leaves from a chestnut tree growing immediately above the Virginia weinschenkite locality, and a rare earth content, largely yttria, by spectroscopic analysis, of 0.06% of the dry leaves, or 1.29% of the ash, was obtained. Approximately eight times as much manganese was present. No yttria was found in oak leaves from the same place.

An analysis was also made of the whitish clay in which the weinschenkite-bearing manganiferous iron oxide occurs. Leaching the clay with hot 1:1 HCl yielded 0.08% of Y_2O_3, and 0.12% P_2O_5. In the compound $Y_2O_3 \cdot P_2O_5$, the weight ratio $Y_2O_3:P_2O_5$ is about 8:5. Apparently, then, much of the P_2O_5 present in the clay, possibly all of it, is not there combined with Y_2O_3 as the mineral weinschenkite. This compound may or may not be present in the clay.

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[12] Van Tongeren, W., *On the Occurrence of the Rarer Elements in Netherlands East Indies*, p. 172, Amsterdam (**1938**).

[13] Goldschmidt, V. M., The principles of distribution of chemical elements in minerals and rocks: *Jour. Chem. Society* (**1937**).

[14] Robinson, W. O., Whetstone, R., and Scribner, B. F., The presence of rare earths in hickory leaves: *Science* **87,** 470 (1938).

Scribner, B. F. *Proc. 6th Summer Conference on Spectroscopy*, pp. 10–13, Wiley & Sons, New York (**1939**).

[15] Drobkov, A. A., *Compt. Rend. Accad. Sci. U.R.S.S.*, **17,** 265–267 (1937).

In any event, there is a very minor concentration of yttrium in the local clay, a larger one in the residual ash of the chestnut leaves, and finally a major concentration as weinschenkite associated with the manganiferous iron oxide.

From the foregoing, it seems reasonable to consider a secular extraction of yttrium from the clay, or local soil, by the growing chestnut and other forest vegetation of the region. As percolating ground waters leach the soil and subsoil, yttrium is to some degree absorbed by the root systems, carried in the sap to the leaves, and thereby concentrated. A single leaf may contain the yttrium originally present in many cubic inches of soil. The humus formed from the leaves may contain yttrium or other rare earths in substantial quantity, perhaps well in excess of what the existing forest growth can utilize in its vital processes, though far too little to permit the formation of recognizable rare-earth minerals. A further agency of concentration is required and this, it is suggested, may be the manganese and iron ore minerals.

Many limonite and psilomelane deposits show a gel-structure, indicative of a present or past colloidal state. Both iron oxide and manganese oxide as they occur subaerially in nature undergo changes in the state of oxidation, with attendant changes in solubility. In general, they are fixed in the higher state of oxidation as limonite and psilomelane, but under reducing conditions, in an acid environment, they tend to dissolve. In a soil environment in a wet season the tendency would be to solution, and in a dry season the minerals would tend to re-form in, at first, a colloidal state. This cycle might repeat itself annually. Of course, it is not implied that the deposit will show these changes en masse, but the surfaces exposed to soil solutions may pass through such a cycle.

This active surface of the ore body may adsorb yttrium ions from the soil solutions, enriched as they are by the action of the regional forest growth, until a concentration is reached sufficient to furnish a visible precipitate with phosphate ions. In the absence of a body of iron-manganese oxide, yttrium ions in the upper soil zone would re-enter the crystalline or colloidal components of the soil, where they would be "trace" elements, and in no way, except perhaps spectroscopically, be detectable. Only at the contact with the ore body are conditions different;

there the yttrium ions, unable to re-enter soil minerals, undergo adsorption on the chemically-active surface of the ore.

In summary, the presence of weinschenkite in the Kelly Bank deposit may be the result of three necessary conditions: first, the biochemical extraction of minute quantities of rare earth metals by trees, especially chestnut and hickory, from the rare earths generally present sparingly in soils, followed by the annual shedding of the leaves in which the rare-earths are concentrated; second, a geological condition of the region such that the forest soil floor remains intact over a long period of time, permitting extended concentration and accumulation of yttrium earths in the humus layer; and, third, the presence of an outcrop of iron-manganese oxides, possibly once, if not now, phosphatic, which may have precipitated the weinschenkite.

Acknowledgments

The writers' thanks are due to Mr. H. D. Miser whose friendly interest promoted this study, to R. C. Wells and W. T. Schaller, who critically read this paper, and to W. E. Richmond, who prepared the *x*-ray films. Joseph M. Axelrod and W. G. Schlecht contributed the section dealing with *x*-ray measurements.

CALCULATION OF DENSITY FROM *X*-RAY DATA*

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In calculating densities of crystals from *x*-ray measurements it is necessary to understand clearly the reasons for differences in the values adopted for Avogadro's number, as noted by Pabst.[1] Pabst's warning should be strongly emphasized. Recent work in the Geological Survey on weinschenkite,[2] including a comparison of observed with calculated densities, has suggested the desirability of a more detailed examination of the factors involved in such calculations. Using the older value 6.060×10^{23} for Avogadro's number, Milton, Murata, and Knechtel calculate from *x*-ray measurements given by Strunz the density 3.270 for Virginia weinschenkite, in good agreement with their observed density 3.263. If they had erroneously used the newer absolute value 6.023×10^{23} for Avogadro's number, their calculated density would be 3.289, in poorer agreement with the observed value.

The present confusion with regard to the scales of *x*-ray wavelength was anticipated by Warren[3] in 1941, and has recently been discussed by Lipson and Riley,[4] Siegbahn,[5] and Wilson,[6] with tentative proposals for an unambiguous notation. Crystal cell dimensions are measured in terms of *x*-ray wavelengths by use of the well known Bragg equation

$$n\lambda = 2d \sin \theta.$$

The direct proportionality of the relation between the value for the wavelength λ of the *x*-rays and the value of the crystal dimension d shows the directly proportional effect of an error in the value of either quantity upon the other. Although the cell dimensions are usually measured on the Siegbahn scale of *x*-ray wavelengths, the reported values have been labeled "Ångstrom units" by most workers. The unit of the Siegbahn scale is not the Ångstrom unit, but the "*X*-unit," defined by an arbitrarily chosen value, 3029.04 X.U. at 18°,[7] for the interplanar distance of calcite crystals. This definition was arrived at by calculating the interplanar distance from the known values for the density and the molecular weight of calcite and for Avogadro's number;

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* Published by permission of the Director, Geological Survey, U. S. Department of the Interior.

[1] Pabst, A., *Am. Mineral.*, **28,** 373 (1943).

[2] Milton, C., Murata, K. J., and Knechtel, M. M., *Am. Mineral.*, **29,** 92–107 (1944).

[3] Warren, B. E., *Jour. Applied Physics*, **12,** 383 (1941).

[4] Lipson, H., and Riley, D. P., *Nature*, **151,** 250, 502 (1943).

[5] Siegbahn, M., *Nature*, **151,** 502 (1943).

[6] Wilson, A. J. C., *Nature*, **151,** 562 (1943).

the value of Avogadro's number was the least accurately known of these quantities. Because Siegbahn chose the best values available at the time for these quantities, the *X*-unit is very nearly equal to one thousandth of an Ångstrom unit; but more recent experimental work has shown that the value of Avogadro's number is lower than the value $(6.0594 \pm 0.0063) \times 10^{23}$ assumed by Siegbahn.[7] This has been confirmed independently by two kinds of experiments. The success of experiments to measure the absolute wavelength of *x*-rays by diffraction from ruled optical gratings first showed a discrepancy between the absolute wavelength scale and the relative wavelength scale based on Siegbahn's assumed interplanar distance for calcite. Careful examination of the experimental results on which the Siegbahn scale was based threw suspicion on the formerly accepted value for the charge on the electron, from which Avogadro's number had been calculated, and when this value was redetermined the result agreed with the grating experiments.[8] As a result of this slight discrepancy, shifting the decimal by three places in the Siegbahn scale readings does not exactly give $10^8 \times$lengths expressed in centimeters, as does the "grating wavelength scale." However, when lattice volumes in Siegbahn units cubed are multiplied by the value for N contained in Siegbahn's "crystal wavelength scale," the incorrect value is cancelled out, so this is the proper value of N to use with lattice constants which are measured on the Siegbahn scale.

If for any reason the length of a lattice parameter in absolute Ångstrom units is wanted, it is found by multiplying the "Siegbahn" distance by the conversion factor $(\lambda_{\text{grating}}/\lambda_{\text{siegbahn}}) = 1.002034 \pm 0.000060$; similarly, volumes in Siegbahn units cubed must be multiplied by the cube of this conversion factor $(\lambda_g/\lambda_s)^3 = 1.0061 \pm 0.0002$, to get the volumes in absolute units. The "best" value of N is at present considered to be $(6.0228_3 \pm 0.0011) \times 10^{23}$ molecules per mole, where the molecular weight is expressed in "chemical atomic mass units." These values are based mainly on the work of Bearden.[9] Reported measurements should be carefully examined to see on which wavelength scale they are expressed.

In calculating the density of a crystal, $\rho = nM/Nv$, the product Nv should be the same whether got by multiplying the volume v of a unit cell in absolute cubic Ångstrom units by the correct value of N, or (since v is equal to the volume in Siegbahn units cubed multiplied by the cube of the wavelength scale conversion factor) by multiplying the volume in

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[7] Siegbahn, M., *Spektroskopie der Röntgenstrahlen*, p. 43 (2nd ed., Berlin, 1931).

[8] An excellent critical and detailed summary of this work may be found in Stranathan. J. D., The "Particles" of Modern Physics, Philadelphia (1942).

Siegbahn units by $N(\lambda_g/\lambda_s)^3$. Using the "best" values given by Birge,[9] $N(\lambda_g/\lambda_s)^3 = (6.0597 \pm 0.0016) \times 10^{23}$, the proper value to use instead of N in calculations with cell volumes measured on the Siegbahn scale. This is practically identical with the value of N assumed by Siegbahn.[7]

The values given above are those for a mole of substance in "chemical atomic mass units," the scale on which atomic weights are reported by chemists. This scale is based on the arbitrarily assumed atomic weight of exactly 16 for the mixture of oxygen isotopes naturally occurring in air. In using data reported by physicists, care must be taken to note that another scale is often used, that of "physical atomic mass units," on which the pure oxygen isotope O^{16} is assigned the atomic weight of exactly 16. The conversion factors

1 physical atomic mass unit = 0.999728 ± 0.000005 chemical atomic mass unit
1 chemical atomic mass unit = 1.000272 ± 0.000005 physical atomic mass unit

are found from mass-spectrographic measurements of the relative abundance of the three oxygen isotopes O^{16}, O^{17} and O^{18} in air, by several workers (Birge[9]).

For convenience, the values to be used under the different circumstances mentioned are summarized in the accompanying table.

Molecular Weight in	Cell Dimensions Measured on	N, molecules per mole	1/N, grams per atomic mass unit
Chemical Atomic Mass Units	Siegbahn Scale	$(6.0597 \pm 0.0016) \times 10^{23}$	$(1.65026 \pm 0.00042) \times 10^{-24}$
	Grating Scale	$(6.0228 \pm 0.0011) \times 10^{23}$	$(1.66035 \pm 0.00030) \times 10^{-24}$
Physical Atomic Mass Units	Siegbahn Scale	$(6.0613 \pm 0.0016) \times 10^{23}$	$(1.64981 \pm 0.00042) \times 10^{-24}$
	Grating Scale	$(6.0245 \pm 0.0011) \times 10^{23}$	$(1.65990 \pm 0.00030) \times 10^{-24}$

I wish to thank Dr. R. C. Wells and Dr. George Tunell for valuable help in the preparation of this note.

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[9] Bearden, J. A., *Jour. Applied Physics*, **12,** 395–403 (1941).

Birge, R. T., *Reports on Progress in Physics*, **8,** 90–134 (1941). (London, *The Physical Society*, **1942**); *Rev. Mod. Phys.*, **13,** 233–239 (Oct. 1941).

CHEMICAL AND MINERALOGICAL COMPOSITION OF TWENTY TYPICAL "LIMONITES"

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For many years it has been known that limonite does not exist as a mineral; that the product formerly listed in textbooks as limonite ($2Fe_2O_3 \cdot 3H_2O$) is ferric oxide monohydrate ($Fe_2O_3 \cdot H_2O$), existing either as goethite or lepidocrocite, with variable amounts of adsorbed and capillary water (1).

It has been known likewise that the limonitic cellular boxwork or sponge structures, which form pseudomorphously after the cleavage or fracture patterns of sulfides and certain other oxidizing minerals in nature, are composed mainly of limonitic jasper (2), even though frequently they may be so embedded in or coated over with pulverulent limonitic particles as to be nearly obscured by the latter.

Despite these more specific identifications the average person, when he hears the term "limonite" used, thinks of it as denoting the reddish, yellowish or brownish deposits formed by decomposing iron-yielding minerals in nature without regard to the individual precipitate involved; and by common consent the word, in recent years, has become accepted as a collective term for designating all supergene ferric oxide precipitates in nature which have not been more specifically identified (3). As such the term serves a convenient and highly useful purpose, especially in field work, even though it is recognized that limonite as a mineral does not exist.

The wide variations in Fe_2O_3 and SiO_2 content of limonitic jasper in the cellular pseudomorphs has not always been realized, however; nor has the extent of the admixed impurities which are present, both in the jasper, and in the granular or pulverulent product for which the term limonite, perhaps, might be more specifically reserved.

In the cellular pseudomorphs, for example, Fe_2O_3 content has been found to range from 11.4% to 73.1%; the complementary SiO_2 content, from 72.6% to 13.5%. Moreover, a complex, made up of various intimately intergrown, usually fine-grained, supergene gangue carbonate minerals, not infrequently takes the place of limonitic jasper in the cellular pseudomorphs, either forming directly as boxwork or, more often, building upon or replacing the limonitic jasper subsequent to the latter's formation. Where a neutralizer is abundant in the ground water, as in limestone and certain other districts, the product is common. At Broken Hill (New South Wales) such supergene gangue carbonate matter, made up of a complex comprising minute intergrowths of calcite, magnesite, rhodochrosite and siderite in varying proportions, may be present locally in amount exceeding the limonitic jasper of the cellular pseudomorphs (4). Upon weathering it yields sufficient pulverulent hydrated ferric oxide from the decomposing siderite to make the thoroughly weathered product, in the hand specimen, virtually indistinguishable from normal gossan.

Hydrated manganese dioxide also may be present, both as a replacement constituent of the limonitic jasper and as a free precipitate. Often its colour is dark brown instead of black. As such it is not readily distinguished in the hand specimen from the limonite in which it is embedded.

Gypsum, too, sometimes serves as the interstitial binding agent for granular limonitic particles (2), itself stained the same brownish colour as the limonite, and thus often mistaken for the latter. Although less general in occurrence than the supergene gangue carbonate it is abundant in some districts, and may constitute more than 25% of a gossan.

But disregarding these occurrences, and considering only the loosely granular or pulverulent, more strictly limonitic material, many impurities still are present. In numerous districts the basic sulfate, jarosite ($K_2O \cdot 3Fe_2O_3 \cdot 4SO_3 \cdot 6H_2O$), is not separately distinguished, and is commonly mistaken for and misnamed "limonite." In districts where arsenopyrite is present scorodite ($FeAsO_4 \cdot 2H_2O$) is common, often effectively hidden by the more abundant limonitic matter, especially if the percentage of scorodite is low and the mineral is well dispersed. If lead minerals are present in such districts mimetite ($3Pb_3As_2O_8 \cdot PbCl_2$) frequently forms, and not uncommonly weathers in part to massicot (PbO). Both mimetite and massicot, thus derived, are widespread in Australia, occurring without necessary regard for geographic or climatic conditions, and often so minutely dispersed through the limonitic matter as to be difficult to detect in the hand specimen (5). In humid climates organic salts of iron often form conspicuous coatings along rock fractures. Most of such organic salts are unstable and eventually alter to one form or other of the ferric oxides, but while they exist they may be readily mistaken for "limonite."

These references are sufficient to show that the ferric oxide component in gossans, usually referred to as "limonite," quite generally is contaminated with admixed impurities.

To furnish an idea of the nature and extent of such impurities, Table 1 is presented. It sets forth the analyses and calculated probable mineralogical compositions of twenty typical limonitic products of diverse origin and distribution, all of which in the hand specimen had the ap-

Table 1

Chemical and Mineralogical Composition of Twenty Typical "Limonites"

ANALYSIS

Probable Mineralogical Composition	% PbO	% ZnO	% Cu	% As	% Fe	% Fe_2O_3	% Mn	% MnO_2	% SO_3	% K_2O	% CaO	% MgO	% CO_2	% Al_2O_3	% SiO_2	% Cl	% Ignition Loss	% Calculated Combined H_2O	% Calculated Additional	Sub-Total	Total	Description
	tr	tr	nil	nil	58.2		nil		1.1	nil	0.7	tr	nil	0.4	1.3	nil	13.6					Rust from iron rail lying upon ground, Mount Isa Mines (Queensland) scrap heap.
Gypsum									1.0		.7							.45			2.15	
Limonitic jasper																						
Ferric oxide monohydrate						83.23												9.36		92.59		
Silica and alumina														.4	1.3					1.7	94.29	
Miscellaneous																					3.56	
																					100.00	
	nd	nd	nd	nd	58.3		1.9		nil	nil	0.15	tr	0.2	tr	0.8	nd	12.5					Botryoidal goethite, Copper Queen mine Bisbee (Arizona). Limestone country rock.
2 Supergene gangue carbonate																						
Calcite											.15		.12							.27		
Siderite					.10								.08						.03	.21	.48	
Limonitic jasper																						
Ferric oxide monohydrate						83.35												9.37		92.72		
Hydrous manganese dioxide								3.00										1.24		4.24		
Silica															.8					.8	97.76	
Miscellaneous																					1.76	
																					100.00	
	nil	nil	tr	nil		59.6	nil		13.2	tr	9.2	tr	tr	nil	0.3	nd	17.8					Pyritic granular gossan over fire country, United Verde orebody (Arizona). Collected 1924. Chloritized rhyolite schist country rock.
3 Gypsum									13.2		9.2							5.92			28.32	
Limonitic jasper																						
Ferric oxide monohydrate						59.6												6.70		66.3		
Silica															.3					.3	66.60	
Miscellaneous																					5.08	
																					100.00	
	nd	nd	nil	tr	36.1		2.1		nil	nil	tr	nil	nil	3.7	31.4	nil	9.9					Limonitic jasper with typical shrinkage cracks, Alpha mine, Kimberly (Nevada). Limestone country rock.
4 Limonitic jasper																						
Ferric oxide monohydrate						51.62												5.80		57.42		
Hydrous manganese dioxide								3.32										1.38		4.70		
Silica and alumina														3.7	31.4					35.1	97.22	
Miscellaneous																					2.78	
																					100.00	
	nil	0.2	nil	3.7	38.7		0.1		nil	nil	tr	nil	0.1	2.3	25.2	nil	11.4					Cellular pseudomorph derived from sulfide mixture of approximately 85% pyrrhotite, 10% arsenopyrite, 5% pyrite. Two Treys mine, Herberton (Queensland). Chloritized quartzite country rock.
5 Smithsonite		.2											.11								.31	
Scorodite				3.7	2.76													1.78	3.16		11.40	
Limonitic jasper																						
Ferric oxide monohydrate						51.39												5.78		57.17		
Hydrous manganese dioxide								.16										.07		.23		
Silica and alumina														2.3	25.2					27.5	84.90	
Miscellaneous																					3.39	
																					100.00	
	nil	0.2	nil	4.2	48.2		nil		nil	nil	tr	nil	0.1	1.9	9.3	nil	13.3					Limonitic cell-filling of No. 5
6 Smithsonite		.2											.1								.31	
Scorodite				4.2	3.13													2.02	3.59		12.94	
Limonitic jasper																						
Ferric oxide monohydrate						64.45												7.24		71.69		
Silica and alumina														1.9	9.3					11.2	82.89	
Miscellaneous																					3.86	
																					100.00	
	nd	nd	tr	nil	60.5		tr		1.2	0.35	nil	nil	nil	tr	3.8	nil	8.1					Imperfect cellular boxwork and relief limonite over clay chalcocite-pyrite orebody, Morenci (Arizona). Collected 1927. Monzonite porphyry country rock.
7 Jarosite						1.79			1.19	.35								.40			3.73	
Limonitic jasper																						
Hematite*						16.20														16.20		
Ferric oxide monohydrate*						68.53												7.70		76.23		
Silica															3.8					3.8	96.23	
Miscellaneous																					.04	
																					100.00	
	nd	nd	2.2	nil	49.1		nil		0.5	0.15	0.6	0.1	1.5	0.6	14.7	nd	8.9					Cellular pseudomorph derived from bornite, Engelmine (California). Gabbro country rock.
8 Malachite			2.2										.76					.31	.28		3.55	
Supergene gangue carbonate																						
Calcite											.6		.47							1.07		
Magnesite												.1	.11							.21		
Siderite					.20								.16						.06	.42	1.70	
Jarosite						.77			.51	.15								.17			1.60	
Limonitic jasper																						
Ferric oxide monohydrate						69.15												7.77		76.92		
Silica and alumina														.6	14.7					15.3	92.22	
Miscellaneous																					.93	
																					100.00	
	nd	nd	1.7	nil	58.0		nil		0.9	0.25	0.2	tr	0.8	0.2	1.6	nd	11.1					Limonitic cell-filling of No. 8.
9 Malachite			1.7										.59					.24	.21		2.74	
Supergene gangue carbonate																						
Calcite											.2		.16							.36		
Siderite					.06								.05						.02	.13	.49	
Jarosite						1.28			.85	.25								.29			2.67	
Limonitic jasper																						
Ferric oxide monohydrate						81.57												9.17		90.74		
Silica and alumina														.2	1.6					1.8	92.54	
Miscellaneous																					1.56	
																					100.00	
	nd	nd	0.4	nil	36.7		tr		tr	tr	2.3	0.4	2.6	0.2	32.1	nd	10.1					Cellular pseudomorph derived from chalcopyrite, with lesser associated pyrite. Kimberly (Nevada). Garnetized limestone country rock.
10 Malachite			.4										.14					.06	.05		.65	
Supergene gangue carbonate																						
Calcite											2.3		1.81							4.11		
Magnesite												.4	.44							.84		
Siderite					.27								.21						.07	.55	5.50	
Limonitic jasper																						
Ferric oxide monohydrate						52.09												5.85		57.94		
Silica and alumina														.2	32.1					32.3	90.24	
Miscellaneous																					3.61	
																					100.00	
	nd	nd	0.5	nil	52.8		nil		0.5	0.10	1.7	0.2	1.8	0.2	6.3	nd	0.8					Limonitic cell-filling of No. 10.
11 Malachite			.5										.17					.07	.06		.80	
Supergene gangue carbonate																						
Calcite											1.7		1.33							3.03		
Magnesite												.2	.22							.42		
Siderite					.10								.08						.03	.21	3.66	
Jarosite						.51			.34	.10								.12			1.07	
Limonitic jasper																						
Ferric oxide monohydrate						74.85												8.41		83.26		
Silica and alumina														.2	6.3					6.5	89.76	
Miscellaneous																					4.71	
																					100.00	
	nd	nd	0.7	tr	51.1		0.1		nil	tr	0.2	nil	0.4	0.7	13.5	nd	11.1					Cellular pseudomorph derived from chalcopyrite with very minor pyrite. Lady Fanny mine (Cloncurry district, Queensland). Hornblende-biotite schist country rock.
12 Malachite			.7										.24					.10	.09		1.13	
Supergene gangue carbonate																						
Calcite											.2		.16								.36	
Limonitic jasper																						
Ferric oxide monohydrate						73.07												8.21		81.28		
Hydrous manganese dioxide								.16										.07		.23		
Silica and alumina														.7	13.5					14.2	95.71	
Miscellaneous																					2.80	
																					100.00	
	0.6	nil	nil	0.1	40.3		0.1		nil	tr	0.4	0.2	0.9	1.4	27.6	0.005	11.4					Limonitic pseudomorph derived from cerussite, Crystal lease, Mount Isa Mines (Queensland). Shale country rock.
13 Cerussite	.45												.09								.54	
Mimetite	.15			.03												.005			.025		.21	
Scorodite				.07	.05													.03	.06		.21	
Supergene gangue carbonate																						
Calcite											.4		.31							.71		
Magnesite												.2	.22							.42		
Siderite					.36								.28						.10	.74	1.87	
Limonitic jasper																						
Ferric oxide monohydrate						57.04												6.41		63.45		
Hydrous manganese dioxide								.16										.07		.23		
Silica and alumina														1.4	27.6					29.0	92.68	
Miscellaneous																					4.49	
																					100.00	
	tr	1.6	nil	0.02	21.4		0.05		nil	nil	0.4	0.2	1.4	2.2	59.0	nil	4.5					Cellular pseudomorph derived from sphalerite. Golconda mine (Chloride district, Arizona).
14 Smithsonite		1.6											.87								2.47	
Scorodite				.02	.015													.01	.02		.065	
Supergene gangue carbonate																						
Calcite											.4		.31							.71		
Magnesite												.2	.22							.42	1.13	
Hypogene quartz (estimated)															3.5						3.5	
Limonitic jasper																						
Ferric oxide monohydrate						30.58												3.44		34.02		
Hydrous manganese dioxide								.08										.03		.11		
Silica and alumina														2.2	55.5					57.7	91.83	
Miscellaneous																					1.005	
																					100.000	
	nil	3.7	nil	0.06	49.6		nil		nil	nil	0.25	tr	2.2	1.2	10.5	nil	11.1					Limonitic cell-filling of No. 14.
15 Smithsonite		3.7											2.0								5.70	
Scorodite				.06	.04													.03	.05		.18	
Supergene gangue carbonate																						
Calcite											.25		.20								.45	
Limonitic jasper																						
Ferric oxide monohydrate						70.87												7.97		78.84		
Silica and alumina														1.2	10.5					11.7	90.54	
Miscellaneous																					3.13	
																					100.00	
	0.3	0.6	0.3	0.03	13.3		0.02		nil	tr	0.5	0.2	1.3	1.1	72.6	nil	4.3					Cellular pseudomorph derived from sphalerite Watson lode (Lawn Hill district, Queensland). Shale country rock.
16 Cerussite	.3												.06								.36	
Smithsonite		.6											.32								.92	
Malachite			.3										.10					.04	.04		.48	
Scorodite				.03	.02													.015	.03		.095	
Supergene gangue carbonate																						
Calcite											.5		.39							.89		
Magnesite												.2	.22							.42		
Siderite					.27								.21						.07	.55	1.86	
Hypogene quartz (estimated)															9.0						9.00	
Limonitic jasper																						
Ferric oxide monohydrate						18.60												2.09		20.69		
Hydrous manganese dioxide								.03										.01		.04		
Silica and alumina														1.1	63.6					64.7	85.43	
Miscellaneous																					1.855	
																					100.000	
	6.0	0.9	nil	5.8	29.7		1.8		1.8	0.5	tr	tr	0.6	3.1	22.6	0.110	10.3					Limonitic derivative from arsenical silver-lead-zinc ore, Mount Bonnie (North Australia). Slate-mica schist country rock.
17 Cerussite	.53												.10								.63	
Smithsonite		.9											.49								1.39	
Mimetite	3.44			.69												.11			.34		4.58	
Massicot	2.03																				2.03	
Scorodite				5.11	3.81													2.45	4.36		15.73	
Jarosite						2.55			1.7	.5								.58			5.33	
Limonitic jasper																						
Ferric oxide monohydrate						34.46												3.87		38.33		
Hydrous manganese dioxide								2.84										1.18		4.02		
Silica and alumina														3.1	22.6					25.7	68.05	
Miscellaneous																					2.26	
																					100.00	
	1.6	2.3	nil	tr	17.1		7.9		tr	nil	4.9	0.3	13.8	0.4	36.7	nd	6.9					Cellular pseudomorph derived from sulfide mixture of estimated 55% marmatite, 40% galena, 5% pyrite-pyrrhotite and miscellaneous. Post-mine leaching, 2000 ft level, North mine, Broken Hill (New South Wales). Sillimanite gneiss country rock.
18 Cerussite	1.6												.32								1.92	
Smithsonite		2.3											1.24								3.54	
Supergene gangue carbonate																						
Calcite											4.9		3.85							8.75		
Magnesite												.3	.33							.63		
Rhodochrosite								6.07 (MnO)					3.77							9.84		
Siderite					5.45								4.29						1.54	11.28	30.50	
Limonitic jasper																						
Ferric oxide monohydrate						16.66												1.87		18.53		
Hydrous manganese dioxide								5.06										2.09		7.15		
Silica and alumina														.4	36.7					37.1	62.78	
Miscellaneous																					1.26	
																					100.00	
	nil	nil	nd	0.013	8.8		1.9		nil	nd	nil	tr	0.2	1.8	72.2	(Cr_2O_3) 3.8	7.7					Cellular derivative from leached massive chromite, Tiebaghi mine (Paagoumene, New Caledonia). Serpentine country rock.
19 Chromite					.6		2									3.8			.23		4.83	
Supergene gangue carbonate																						
Siderite and magnesite					.25							tr	.2						.07		.52	
Limonitic jasper																						
Ferric oxide monohydrate						11.37												1.28		12.65		
Hydrous manganese dioxide								2.69										1.11		3.80		
Silica and alumina														1.8†	72.2					74.0	90.45	
Miscellaneous (including unallocated 0.013% As. much of remainder probably is organic matter)																					4.20	
																					100.00	
	nil	tr	nil	tr		(FeO) 11.4		(MnO) 15.1	nd	nd	35.5	0.3	29.0	nil	0.7	(F) 13.6	2.1					Cellular derivative from imperfectly-leached fluorite. Post-mine leaching, 2000-ft. level, North mine, Broken Hill (New South Wales) Sillimanite gneiss country rock.
20 Fluorite											14.21‡					13.6					27.81	
Supergene gangue carbonate																						
Calcite											15.61		12.25							27.86		
Magnesite												.3	.33							.63		
Rhodochrosite								15.1					9.38							24.48		
Siderite						11.4							6.99							18.39	71.36	
Silica															.7						.70	
Miscellaneous																					.13	
																					100.00	

* Theoretical hematite, minimumand goethite maximum. Hematite probably greater.

† Part of Al_2O_3 probably present as spinel associated with chromite. For convenience all Al_2O_3 is included with limonitic jasper.

‡ Calculated as Ca.

Note. Fe_2O_3 calculated from available Fe in all cases except No. 3. MnO_2 calculated from available Mn in all cases.

Analyses by P. F. Boswell. Nos. 2, 3, 4, 7, 8, 9, 10, 11, 14, 15.

Analyses by Mount Isa Mines Limited laboratory. Nos. 1, 5, 6, 12, 13, 16, 17, 18, 19, 20.

Miscellaneous comprises mainly adsorbed and capillary water.

pearance of, and were commonly referred to, as "limonite" in the districts in which they occurred. They have been chosen as typical from a much larger group of analyses which the author has accumulated in his work during the past twenty-five years, and represent both normal and extreme types. Calculated mineralogical compositions are based upon combined analyses and microscope examination of the powdered material. In most cases analyses were carried only to one decimal. Exceptions are K_2O and Cl. The former was determined to the nearest 0.05%; the latter, to the nearest 0.005%.

In preparing the material for analysis, detectable country rock was excluded, as was all other observed extraneous material except the hypogene quartz of Nos. 14 and 16. Hypogene quartz could not be satisfactorily removed in those two instances without detriment to the supergene material.

Supergene gangue carbonate matter comprises the fine-grained, minutely-intergrown material which either formed more or less exclusively as the boxwork of No. 20, or was precipitated as a coating upon or replacement of the previously-formed limonitic jasper mentioned on page 37. No detectable hypogene gangue carbonate is involved.

Kaolin has been observed under the microscope replacing the supergene gangue carbonate complexes, but most of the alumina of the analyses probably represents minute specks of impure clayey matter deposited by ground water. Precipitation from ground water likewise accounts for the small content of silica in cases, such as No. 2, where normally no silica would be expected.

Because under the microscope no magnesium silicate was detected in any of the specimens, all magnesia is calculated as magnesite. In small amount it was identified in the eight specimens listed as containing it.

In all cases siderite was calculated to consume CO_2 remaining after requirements of calcite and magnesite (also rhodochrosite in Nos. 18 and 20) had been met. It was identified in seven of the ten specimens listed as containing it.

"Miscellaneous" comprises mainly adsorbed and capillary water. In some instances it may include organic matter, and possibly small amounts of CO_2.

Hematite was not detected in powdered material of the twenty listed specimens other than in No. 7, where it was clearly distinguished as a fine-grained co-precipitate with much more abundant goethite.

Tunell has shown that, intergrown with goethite and jarosite, hematite is not uncommon as a supergene derivative in certain of the leached disseminated copper deposits of southwestern United States (6). Its formation in small amount by spontaneous crystallization from hydrous ferric oxide under surface conditions has been established by Raymond (7).

It is noteworthy however that, except in the disseminated copper deposits where often it forms as a partial limonitic filling of the cavities vacated by the leached sulfides, or occurs as tiny veinlets along fractures, hematite as a supergene product has been observed only rarely in the Leached Outcrop Investigation. In gossans derived from massive or semi-massive sulfides it is virtually absent.

Because of its scarcity or complete absence in most of the material listed in Table 1, it thus seems necessary to conclude, from the analyses listed in the table, that ferric oxide monohydrate may and frequently does exist in porous gossans with too low a content of adsorbed and capillary water to conform with the theoretical formula ($2Fe_2O_3 \cdot 3H_2O$) for limonite.

The twenty products listed in the table, though in a few instances comprising extreme types, are on the whole representative of the material which, as gossan, normally passes for "limonite." They illustrate both the wide variations in composition, and extent and nature of the impurities, present in such material.

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MEMORIAL OF WILLIAM SHIRLEY BAYLEY

Clarence S. Ross, *U. S. Geological Survey, Washington, D. C.*

William Shirley Bayley, fellow of the American Mineralogical Society and who had served the Society as councilor and president, died at the home of his daughter, Elizabeth Gillen, February 14, 1943.

Dr. Bayley continued active work at Urbana, Illinois, as business editor of *Economic Geology* until November 1942, although for some years his health had made it necessary for him to conserve his strength with the utmost care. In November 1942, failing strength led him to join his daughter at Glen Rock, New Jersey, where he spent his last months happily enjoying the company of her family. He was buried in Urbana, Illinois, where he had made his home for 35 years.

William Shirley Bayley was born November 10, 1861, in Baltimore, Maryland, the son of Robert P. and Emma (Downing) Bayley. He received his A.B. degree in 1883, and the Doctor of Philosophy degree in 1886, from Johns Hopkins University. On March 11, 1894, he was married to Lucie Jacobs of Bel Air, Maryland.

Dr. Bayley maintained his membership in the United States Geological Survey throughout his career; that is, from 1885 to the time of his death. He was professor of geology at Colby College from 1888 to 1904, at Lehigh University from 1904 to 1906, and was called to the University of Illinois in 1906. Here he was assistant professor, 1906–1909, associate professor from 1909 to 1913, and professor from 1913 to 1931, being head of the Department of Geology from 1928 to 1931, and Professor Emeritus 1931 to 1943. He was business editor of *Economic Geology* from its founding in 1905 until a few months before his death. He was an original fellow of the Geological Society of America, councilor, 1919 to 1921, vice president 1929 and 1937; member of the Society of Economic Geologists, councilor 1925 to 1927, vice president 1932; a fellow of the American Mineralogical Society, councilor 1931 to 1934, president 1936; member of the Illinois Academy of Sciences, president 1923; member of the Geological Society of Washington; a member of the American Association for the Advancement of Science; and fellow of the Chemische Gesellschaft; member of the Committee of the Crockerland Expedition, and chairman of the University of Illinois section; associate editor of *American Naturalist* 1886–1902; and reviewer for *Neues Jahrbuch für Mineralogie*, Berlin, 1890–1908. He was a member of Phi Beta Kappa, Sigma Xi, and Beta Theta Pi.

Dr. Bayley had the exceptional opportunity at Johns Hopkins University of working under two of America's most inspiring teachers, Ira

WILLIAM SHIRLEY BAYLEY
1861–1943

Remson in chemistry and George H. Williams in petrology. These associations led him to have a keen appreciation of the importance of a thorough knowledge of minerals and of chemistry in solving geologic problems; and he stressed these points not only in his own geologic work, but also in his teaching. The association with Williams, the father of American petrology, led him to become interested in the origins and genetic relationships of minerals and rocks, even at a time when only a description was the dominant interest of most workers in these sciences.

On July 1, 1885, Dr. Bayley began his work in the Lake Superior region—at first, as a volunteer assistant—for the United States Geological Survey, his work in the region continuing for the next 18 years. His interest in petrologic problems led him, in company with Williams, to begin a study of the rocks of Pigeon Point, Minnesota, a classical area in its bearing on the relative importance of differentiation and assimilation in the formation of igneous rocks.

The following summer Bayley and Williams determined that the schists at the Falls of the Menominee River were derived from "acidic and basic eruptives." Later that summer Dr. Bayley traced the contact between the granite and the Animiké slates, being the first geologist to traverse the full length of the Mesabi Range. The following years were devoted largely to field work and the preparation of a report in joint authorship with Van Hise on the Marquette Iron Range which was published as *United States Geological Survey Monograph* **28**. He also had a part in the preparation of *Monograph* **36** on the Crystal Falls iron-bearing district. From 1895 to 1902 Dr. Bayley was engaged in field work in both the Menominee and Vermillion districts and in 1902 completed his report on the Menominee district which was published as *Monograph* **48** in 1904.

In 1903 Dr. Bayley began his studies of the geology of the highlands of New Jersey and assisted in the preparation of the Passaic and Raritan Folios. Later he made a detailed report on the iron mines of the state for the New Jersey State Geological Survey.

In 1909 he had a part in the study of the Llano-Burnet region of Texas.

In 1917 Dr. Bayley began studies of the kaolin deposits for the North Carolina Geological Survey. Later, in cooperation between the North Carolina, Tennessee, and United States Geological Surveys, he made a detailed study of the iron ores of the region. Papers were published on the magnetite ores, the brown hematites, and the rutile-magnetite ores, and in particular on the magnetite ores of the Cranberry area. In 1927 he made a detailed study of the Tate Quadrangle of Georgia, an area significant for its wide variety of crystalline rocks and for the marbles for which it is famous.

Geologic problems involving crystalline rocks, the Lake Superior and other iron ores, and their related problems on which Dr. Bayley worked for so many years, provided the background for his teaching in mineralogy, crystallography, petrology, and economic and engineering geology, the subjects in which he specialized. However, Dr. Bayley's own experience and broad interests led him to insist on a thorough training in the fundamental sciences for his students. This applied not only to students in geology, but also to those in chemistry, engineering, and especially to those in ceramic engineering. Indeed he made very real contributions to the ceramic industry, for many ceramic engineers who make effective use of petrographic methods owe much to his teaching. These teaching interests led to the preparation of text books in mineralogy, crystallography, and petrology.

At Colby College and later at the University of Illinois, Dr. Bayley was zealous in the maintenance of the highest standards, never being content with less than the best from himself, from fellow faculty members, or from his students. He served on many important committees where his unflagging labors contributed materially to the best interests of the University and the State.

Dr. Bayley's high ideals as a scientist and as a teacher were respected by all who knew him, and were only equaled by the breadth and loyalty of his friendships. His friendship with his students was particularly close, for although they had the utmost respect for him as an inspiring teacher, it is as a friend and councilor that they particularly cherish his memory.

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In addition many book reviews written by W. S. Bayley were published in *Economic Geology*.

MEMORIAL OF ALBERT BECKER PECK

Walter F. Hunt, *University of Michigan,*
Ann Arbor, Michigan.

The news of the sudden death of Albert Becker Peck on Saturday, February 13, 1943, came as a distinct shock to his associates and numerous friends and acquaintances. He began the spring term with his usual teaching assignment and there was no indication that he was not in normal health. Saturday morning he performed his usual laboratory duties and spent the evening with a small group of intimate friends. Almost immediately upon his return home he was stricken with a heart attack and passed away before medical aid could be summoned. Professor Peck was fifty years of age.

Albert Becker Peck was born September 19, 1892, at Syracuse, New York, the son of Professor Henry Allen and Kitty Becker Peck. His entire life was spent in an academic environment, as his father was for many years Professor of astronomy and Dean of the Liberal Arts College of Syracuse University, and had also served as Vice-Chancellor of the University. After receiving the degree of Bachelor of Arts at Syracuse in 1914, he came to the University of Michigan for his graduate studies. In 1915 the University of Michigan conferred upon him the degree of Master of Arts and in 1925 that of Doctor of Philosophy.

His teaching assignment began as an assistant in mineralogy in 1914. In 1916 he was promoted to an instructorship. He temporarily severed his connection with the University in 1917 to accept the position of assistant physicist in charge of petrographic investigations in the Division of Ceramics of the United States Bureau of Standards in Pittsburgh, Pa., and Washington, D. C. His work with the Bureau was so satisfactory that at the end of two years he was advanced to the rank of associate physicist. While at the Bureau his duties were essentially of a research nature and related to investigations pertaining to changes in the microstructure of portland cement, porcelains and various refractories.

In 1920 Professor Peck returned to the University of Michigan with the rank of Assistant Professor of mineralogy. His productive scholarship and excellence as a teacher were recognized by advancement to Associate Professor in 1927 and to Professor in 1942.

Professor Peck was a charter fellow of the Mineralogical Society of America and an active member of the American Ceramic Society. He held responsible positions in both of these organizations. In the latter he was affiliated with the white wares and refractories divisions and was

Albert Becker Peck
1892–1943

chairman of the Detroit local section from 1924–1926. He was elected the first treasurer of the Mineralogical Society of America when that organization was founded in 1919 and held this office for four years. Again in 1929 he served as treasurer of the Society and in 1933 as secretary. He attended the annual meetings of both societies quite regularly and always took an active part in the discussion of the papers. He also held membership in Sigma Xi, Michigan Academy of Science, Arts, and Letters, and the University Research Club.

Professor Peck was a very capable teacher, especially in the more advanced courses where he could utilize to best advantage the experience acquired in various industrial contacts. He served for many years as a consulting petrographer in ceramic investigations for the Champion Spark Plug Co., Detroit, Michigan; the Libbey-Owens Sheet Glass Co. and Libbey Glass Co., Toledo, Ohio; and for the Sterling Grinding Wheel Co., Tiffin, Ohio. In his capacity as a consultant his duties pertained mainly to the development of special porcelains and refractories, the elimination of causes of glass stones, and the determination of the mineralogical constitution and microstructure of grinding-wheel bonds.

He was an exceedingly conscientious worker, moving about quietly, yet effectively, and shunned all forms of publicity. During twenty-four years of his University service he asked for only one sabbatical leave. That semester and the following summer were spent in study at the University of Arizona and at Harvard University, followed by travel in Europe where he visited mineralogical research laboratories and industries. Upon his return a new course was offered in the department which embodied the technique he acquired while on leave. His duties and reports on committee assignments reveal the same painstaking consideration and evaluation of the factors involved that characterized all his undertakings.

Professor Peck's list of publications shows twenty-one papers, exclusive of numerous reviews and abstracts of American and foreign books and papers on mineralogical and geological subjects. While his publications are somewhat varied in character, they might be grouped under three main headings: (1) Morphological and thermo-optical studies of minerals and short articles of general mineralogical interest. (2) Papers representing the result of a continuous cooperative program of research on the application of uncommon or hitherto unused minerals to new commercial uses for special high duty porcelains and refractories. (3) Papers dealing with general phases of ceramics, especially those involving the use of the petrographic microscope. In this field Professor Peck was a recognized authority.

Beginning in 1917 at the Bureau of Standards and since 1920 at the University of Michigan he had been continuously in touch with the development of new commercial uses for minerals and synthetic products in the field of ceramics. In the paper on "Changes in the constitution and microstructure of andalusite, cyanite, and sillimanite at high temperatures and their significance in industrial practice," Professor Peck recorded the first detailed study and correlation of the firing properties and changes in microstructure of these minerals under conditions of industrial practice. Since certain types of equipment for such investigations are lacking at the University of Michigan, much of this work necessarily had to be of a cooperative nature with private industrial research laboratories, such as the Champion Spark Plug Company of Detroit. While some publication of these studies is possible, much cannot be released at present because of its strictly confidential character.

It is also of considerable interest to note the discovery by Professor Peck and determination of the composition of an unknown glass stone, later confirmed by work of the Geophysical Laboratory on the system Na_2SiO_3–$CaSiO_3$–SiO_2. The identification of the nature of glass stones is of the utmost importance in correcting defects in glass manufacture.

The Department of Mineralogy and the Mineralogical Society have lost an able, independent investigator and effective teacher. His quiet manner, his ability to present the essentials of a difficult subject in a systematic, well organized manner and his insistence on a high grade of student performance are attributes we all admire and strive to attain.

On December 22, 1917, Professor Peck married Mildred Wood of Syracuse, New York. Professor Peck is survived by his wife and son, Robert Allen Peck, formerly a student in Princeton University who has recently completed the Army meteorological training course at Haverford, Pennsylvania.

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MINERALOGICAL SOCIETY OF AMERICA
PROCEEDINGS FOR 1943

PAUL F. KERR, *Secretary.*

Because of the wartime situation no meeting of the Mineralogical Society of America was held in 1943. The Council of the Society assembled in New York City on December 11 to review the business of the Society for the year and to make such arrangements as were deemed necessary to continue the affairs of the organization for another year. The various reports of the officers of the Society for the year are submitted herewith.

ELECTION OF OFFICERS AND FELLOWS FOR 1944.
REPORTS OF THE EDITOR, TREASURER, SECRETARY AND AUDITING COMMITTEE.
LIST OF FORMER OFFICERS AND MEETING PLACES OF THE SOCIETY.
CORRESPONDENTS, FELLOWS, MEMBERS, AND SUBSCRIBERS OF THE MINERALOGICAL SOCIETY OF AMERICA.

ELECTION OF OFFICERS AND FELLOWS FOR 1944

The secretary announces that 337 ballots have been cast for the officers of the society as nominated by the Council. Officers for 1943 are:

President: R. C. Emmons, University of Wisconsin, Madison, Wisconsin.
Vice-President: Harry Berman, Harvard University, Cambridge, Massachusetts.
Secretary: Paul F. Kerr, Columbia University, New York, New York.
Treasurer: Earl Ingerson, Geophysical Laboratory, Washington, D. C.
Editor: Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.
Councilor, 1944–1947: S. J. Shand, Columbia University, New York, New York.

The secretary announces that according to the provisions of the constitution the following have been elected to fellowship:

Anderson, Alfred Leonard, Cornell University, Ithaca, New York.
Bell, James Forbes, War Production Board, Washington, D. C.
Bradley, William F., Illinois State Geological Survey, Urbana, Illinois.
Cameron, Eugene Nathan, Columbia University, New York, N. Y.
Chapman, Carleton A., University of Illinois, Urbana, Illinois.
Coats, Robert Roy, U. S. Geological Survey, Washington, D. C.
Faessler, Carl, Laval University, Quebec, Canada.
Galbraith, Frederic William, University of Arizona, Tucson, Arizona.
Gallagher, David, U. S. Geological Survey, Washington, D. C.
Grawe, Oliver R., Missouri School of Mines, Rolla, Missouri.
Hallimond, Arthur Francis, Geological Survey and Museum, London, England.
Howland, Arthur Lloyd, Northwestern University, Evanston, Illinois.
Keevil, Norman Bell, University of Toronto, Toronto, Canada.
Keller, Walter D., University of Missouri, Columbia, Missouri.
Milton, Charles, U. S. Geological Survey, Washington, D. C.
Osborn, Elburt Franklin, Geophysical Laboratory, Washington, D. C.

REPORT OF THE SECRETARY, 1943

	1942	1943	Gain	Loss
Correspondents	6	6	—	—
Fellows	199	209	16	6
Members	418	462	123	79
Subscribers	268	288	29	9
	891	965	168	94

A net membership gain of 74 for the year 1943 stands out in contrast to a net loss in membership of 48 for the year 1942. This has occurred in spite of the dislocation of so many of those on our membership roll, and is a clear indication of sustained interest in the Society and its work despite the inconveniences, demands, and exigencies of war. Few of our members in foreign countries, with whom we have direct communication, have withdrawn. Their interest and loyalty are noteworthy. Small gains from foreign countries have occurred, principally from those in the Western Hemisphere.

Another interesting observation is that few issues of our Journal have been returned because of non-delivery, an indication that the members and subscribers have promptly given notification of change of address. Numerous requests have been received from men in the service, asking to have *The American Mineralogist* forwarded to them as long as they are in the United States.

It should be noted that, notwithstanding wartime conditions, the membership as of December 31, 1943, stands at the highest level in the history of the Society except for 1939 when the total was 1042. This includes correspondents, members, fellows, and subscribers.

Respectfully submitted,
Paul F. Kerr, *Secretary*

REPORT OF THE EDITOR FOR 1943

To the Council, Fellows and Members of the Mineralogical Society of America:

The major effect of the present Global War; insofar as the Journal for 1943 is concerned, is reflected in a considerably smaller volume for the current year. This retrenchment was not due to financial reasons but rather to a substantial reduction in the number of contributions received. This condition was not entirely unexpected. *The American Mineralogist* is not unique in this respect. Quite a number of scientific publications are likewise passing through this same period of depression. We operate in a rather restricted field of natural science and much of our manpower has been diverted to efforts pertaining either directly or indirectly to the war effort.

This tendency of a partial drying up of our usual sources of manuscript supply was noted in the early months of the current year and on May 1 a circular letter was sent to the officers of the Society, the members of the council and to the associate editors calling attention to this condition and suggesting, as an emergency measure, the adoption of a policy of combining the issues of two months in a single number. This arrangement would permit of greater flexibility as the size of the number could be adjusted according to the material on hand.

This new policy became effective July 1 and thus the last six months of the year are represented by three numbers of the combination type referred to above. In times such as these it is difficult to plan too far in advance, but as far as 1944 is concerned every effort will be made to continue this policy, namely, of issuing the Journal bimonthly. Sufficient material is on hand at present to carry us through until early summer. It should be understood, however, that this arrangement is temporary and that our regular schedule of a monthly periodical will again be resumed when conditions become normal and the supply of contributions warrants such a change.

In the editor's report last year reference was made to delays encountered due to the fact that approval of the Board of Economic Warfare was necessary before any issue could be printed and distributed. The examination of the proof material was for the purpose of determining whether or not the issue should be exported. No issue of *The American Mineralogist* was refused this privilege, but an additional ten days or two weeks were required to clear this hurdle. I am happy to announce at this time that this restriction has now been removed from scientific journals (effective July 1, 1943). The responsibility of accepting and printing material that will not benefit the enemy is now placed directly on the editor.

While a restrictive measure by the War Production Board on the use of paper was issued this past year, this restriction did not affect our Journal as our consumption of paper this year will be less than in 1942. A restriction however on the use of binder's wire has affected authors' reprints which unfortunately are not now so securely stapled as in former years.

Recognition and appreciation is here expressed for the financial assistance received from the Geological Society of America. The council of that body very graciously voted to contribute $2000 during 1943 to help defray publication costs, and I am informed that a recommendation is being made to the new council of the G.S.A. to continue this aid during 1944.

In reviewing the accomplishments of the Journal for 1943, we find that volume 28 contains 618 pages, exclusive of index. This represents approximately a 200 page decrease (25%) when compared with the previous year. This is the smallest volume issued by the Society since 1934. Leading articles, which number 43, occupy 84.3% of the total space of the Journal. The average length of the leading articles is slightly greater than 12 printed pages. Table 1 which accompanies this report indicates the distribution of the leading articles in the eight fields covered by *The American Mineralogist*. If to the main articles we add 14 shorter papers, appearing under the heading of Notes and News, we obtain a total of 57 published manuscripts for the calendar year. These contributions were received from 68 contributors associated with 41 different universities, research bureaus and technical laboratories. The journal for 1943 carries detailed descriptions of five new minerals: endellite, gamagarite, partridgeite, sillenite, and beyerite. One hundred eighty-seven illustrations of various types assist in clarifying the descriptive portions of the text. As in previous years some financial aid was received from authors or institutions when the cost of cuts for any single article seemed excessive.

It is also of considerable interest to note that contributions continue to reach us from sources beyond our own borders. During 1943 we printed 10 such manuscripts received from the following five countries: Australia 1, Canada 3, England 2, Soviet Russia 1, and Union of South Africa 3.

Figure 1 is a graph illustrating the growth of the Journal from 1916 to the present time. The special "Palache number" with its 431 pages, financed largely by friends of Harvard University, was responsible for the high peak reached in 1937.

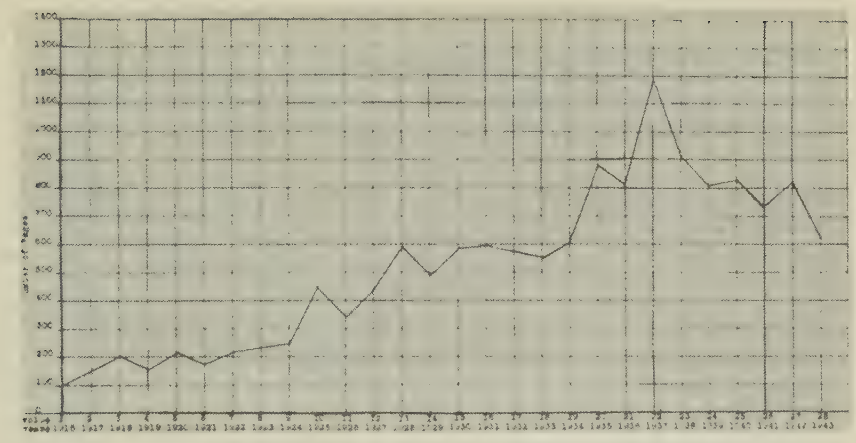

FIG. 1

The accompanying table of contents summarizes in detail the distribution of subject matter in volume 28.

TABLE 1. DISTRIBUTION OF SUBJECT MATTER IN VOLUME 28

Subjects	*Articles*	*Pages*	*Per Cent of Total*
Leading articles*			
Descriptive mineralogy	10		
Chemical mineralogy	6		
Structural crystallography	5		
Geometrical crystallography	5		
Petrography	6		
Optical mineralogy	3		
Mineralography	2		
Memorials, miscellaneous	6		
	43	521.0	84.3
Short articles	14	37.5	15.7
Notes and news	10	4.0	
Abstracts of new mineral names	29	8.5	
Proceedings of societies	20	37.0	
Book reviews	11	10.0	
Total entries	127	618.0	100.0
Illustrations	187		
Index, Title page, Table of contents		12.0	
Grand total		630.0	

* (Average length of leading articles, 12.1 printed pages).

Respectfully submitted,
WALTER F. HUNT, *Editor*

REPORT OF THE TREASURER FOR 1943

To the Council of the Mineralogical Society of America:

Your treasurer submits herewith his annual report for the year beginning December 1, 1942, and ending November 30, 1943.

RECEIPTS

Cash on hand December 1, 1942	$ 1,953.27
Dues and subscriptions	3,009.85
Sale of back numbers	399.11
Authors' charges on separates	611.28
Sale of 20-volume index	19.80
Interest and dividends from endowment	2,612.00
Partial payments (1943) on principal of Trenton Mortgage Service Company's preferred stock	132.57
Geological Society of America Grant for 1943	2,000.00
Advertisements	307.46
Aid on cost of illustrations for papers	226.08
	$11,271.42

DISBURSEMENTS

Printing and distribution of the Journal (10 issues)	$ 4,747.12
Printing and distribution of separates	682.67
To the Editor, Secretary, and Treasurer	970.00
Postage	95.08
Printing and stationery	111.97
Office equipment	4.35
Clerical help	321.00
Committee expenses	4.47
Safety deposit box	9.60
Refund on overpayment	1.00
Returned checks	6.30
	$ 6,953.56
Cash balance November 30, 1943	4,317.86
	$11,271.42

The endowment funds of the Society as of November 30, 1943, consist of the following securities:

45	$1,000 bonds, City and County of Honolulu, Territory of Hawaii, Water Works, 5%, due April 15, 1954	$45,000.00
4	$100 bonds, Great Northern Railway Company, Genl. Mtg., 5½%, due January 1, 1952	400.00
37	514/1000 shares, Trenton Mortgage Service Company, Trenton, New Jersey, preferred stock	2,452.19
15	shares, American Telephone and Telegraph Company, common stock	1,728.07*
5	shares, Public Service of New Jersey, 8% preferred stock	702.00*
5	shares, United States Steel, 7% preferred stock	502.45*
10	shares, Consolidated Edison, 5% preferred stock	1,066.64*
20	shares, Union Pacific Railroad Co., 4% preferred stock	1,607.75*
		$53,459.10

* Purchase price.

Respectfully submitted,
Earl Ingerson, *Treasurer*

REPORT OF THE AUDITING COMMITTEE

To the President of the Mineralogical Society of America:

The Auditing Committee has examined and verified the accounts of the Treasurer of the Mineralogical Society of America, for the fiscal year ending November 30, 1943. The securities listed in the Treasurer's report, with all future coupons on the coupon bonds attached, are in the safety deposit box at the Friendship Branch of the Riggs National Bank of Washington, D. C.

Respectfully submitted,
Rollin E. Stevens, *Chairman*
George T. Faust
O. F. Tuttle

DANA FUND

No disbursement made during the fiscal year 1943. Interest received = $11.42. Available balance, November 30, 1943 = $924.85.

Respectfully submitted,
Waldemar T. Schaller

LIST OF FORMER OFFICERS AND MEETING PLACES

By recommendation of the Council, a complete list of past officers is printed in the proceedings of the annual meeting of the Society:

Presidents		Vice-Presidents
1920	Edward H. Kraus	Thomas L. Walker
1921	Charles Palache	Waldemar T. Schaller
1922	Thomas L. Walker	Frederick A. Canfield
1923	Edgar T. Wherry	George F. Kunz
1924	Henry S. Washington	Washington A. Roebling
1925	Arthur S. Eakle	Herbert P. Whitlock
1926	Waldemar T. Schaller	George Vaux, Jr.
1927	Austin F. Rogers	George L. English
1928	Esper S. Larsen	Lazard Cahn
1929	Arthur L. Parsons	Edward Wigglesworth
1930	Herbert E. Merwin	John E. Wolff
1931	Alexander H. Phillips	William F. Foshag
1932	Alexander N. Winchell	Joseph L. Gillson
1933	Herbert P. Whitlock	Frank N. Guild
1934	John E. Wolff	William A. Tarr
1935	Clarence S. Ross	Ellis Thomson
1936	William S. Bayley	Harold L. Alling
1937	Norman L. Bowen	H. V. Ellsworth
1938	Ellis Thomson	Kenneth K. Landes
1939	Max N. Short	Burnham S. Colburn
1940	William F. Foshag	Ian Campbell
1941	Frederick E. Wright	William J. McCaughey
1942	Arthur F. Buddington	Martin J. Buerger
1943	John F. Schairer	John W. Gruner

Secretaries	
1920–1922	Herbert P. Whitlock
1923–1933	Frank R. Van Horn
1933–1934	Albert B. Peck
1934–	Paul F. Kerr

Treasurers	
1920–1923	Albert B. Peck
1924–1929	Alexander H. Phillips
1929–1930	Albert B. Peck
1931–1940	Waldemar T. Schaller
1941–	Earl Ingerson

Editors	
1920–1921	Edgar T. Wherry
1922–	Walter F. Hunt

Councilors

1920 Arthur S. Eakle, Frank R. Van Horn, Fred. E. Wright, Alexander H. Phillips.
1921 Frank R. Van Horn, Fred E. Wright, Alexander H. Phillips, Austin F. Rogers.
1922 Fred E. Wright, Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson.
1923 Alexander H. Phillips, Austin F. Rogers, Thomas L. Watson, Esper S. Larsen.
1924 Austin F. Rogers, Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons.
1925 Thomas L. Watson, Esper S. Larsen, Arthur L. Parsons, William F. Foshag.

1926 Esper S. Larsen, Arthur L. Parsons, William F. Foshag, William A. Tarr.
1927 Arthur L. Parsons, William F. Foshag, William A. Tarr, Alexander N. Winchell.
1928 William F. Foshag, William A. Tarr, Alexander N. Winchell, Ellis Thomson.
1929 William A. Tarr, Alexander N. Winchell, Ellis Thomson, Clarence S. Ross.
1930 Alexander N. Winchell, Ellis Thomson, Clarence S. Ross, Paul F. Kerr.
1931 Ellis Thomson, Clarence S. Ross, Paul F. Kerr, William S. Bayley.
1932 Clarence S. Ross, Paul F. Kerr, William S. Bayley, William J. McCaughey.
1933 Paul F. Kerr, William S. Bayley, William J. McCaughey, Kenneth K. Landes.
1934 William S. Bayley, William J. McCaughey, Kenneth K. Landes, E. P. Henderson.
1935 William J. McCaughey, Kenneth K. Landes, E. P. Henderson, J. F. Schairer.
1936 Kenneth K. Landes, E. P. Henderson, J. F. Schairer, Arthur F. Buddington.
1937 E. P. Henderson, J. F. Schairer, Arthur F. Buddington, Arthur P. Honess.
1938 J. F. Schairer, Arthur F. Buddington, Arthur P. Honess, R. C. Emmons.
1939 Arthur F. Buddington, Arthur P. Honess, R. C. Emmons, Carl Tolman.
1940 Arthur P. Honess, R. C. Emmons, Carl Tolman, D. Jerome Fisher.
1941 R. C. Emmons, Carl Tolman, D. Jerome Fisher, Martin A. Peacock.
1942 Carl Tolman, D. Jerome Fisher, Martin A. Peacock, Adolf Pabst.
1943 D. Jerome Fisher, Martin A. Peacock, Adolf Pabst, C. S. Hurlbut, Jr.

ANNUAL MEETING PLACES

1920 Chicago, Illinois
1921 Amherst, Massachusetts
1922 Ann Arbor, Michigan
1923 Washington, D. C.
1924 Ithaca, New York
1925 New Haven, Connecticut
1926 Madison, Wisconsin
1927 Cleveland, Ohio
1928 New York, N. Y.
1929 Washington, D. C.
1930 Toronto, Canada
1931 Tulsa, Oklahoma
1932 Cambridge, Massachusetts
1933 Chicago, Illinois
1934 Rochester, New York
1935 New York, N. Y.
1936 Cincinnati, Ohio
1937 Washington, D. C.
1938 New York, N. Y.
1939 Minneapolis, Minnesota
1940 Austin, Texas
1941 Boston, Massachusetts
1942 No meeting held
1943 No meeting held

CORRESPONDENTS, FELLOWS, MEMBERS AND SUBSCRIBERS OF THE MINERALOGICAL SOCIETY OF AMERICA

CORRESPONDENTS

Eskola, Pentti, Geological Survey of Finland, Helsingfors, Finland.
Fersman, A. E., Geological and Mineralogical Museum, Academy of Science, Leningrad, U.S.S.R.
Lacroix, A., Museum of Natural History, Paris, France.
Slavik, Frantisek, Charles University, Prague VI, Czechoslovakia.
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Tilley, C. E., Cambridge University, Cambridge, England.

FELLOWS AND MEMBERS

(* Indicates Fellow)

*Adams, Elliot Q., Lamp Development Laboratory, Nela Park, Cleveland, Ohio.
Adams, John W., Empire Zinc Company, Hanover, New Mexico.
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*Billings, Marland P., Harvard University, Cambridge, Massachusetts.
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Bokovoy, Samuel, 75 Elmwood Road, Verona, New Jersey.
*Bowen, Norman L., University of Chicago, Chicago, Illinois.
*Bowles, Oliver, U. S. Bureau of Mines, Washington, D. C.

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*BULLARD, FRED M., 903 West 30 Street, Austin, Texas.
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CALLAHAN, WILLIAM H., Franklin, New Jersey.
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*CAMERON, EUGENE N., Columbia University, New York 27, New York.
*CAMPBELL, CHARLES D., U. S. Geological Survey, Colville, Washington.
*CAMPBELL, IAN, California Institute of Technology, Pasadena, California.
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CARL, HOWARD F., 1615 Noyes Drive, Silver Spring, Maryland.
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*CHAPMAN, CARLETON A., Department of Geology, University of Illinois, Urbana, Illinois.
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*CHAPMAN, RANDOLPH, Department of Geology, Johns Hopkins University, Baltimore Maryland.
CHAYES, FELIX, 4104 Queensbury Road, Hyattsville, Maryland.
CHESLEY, FRANK G., Massachusetts Institute of Technology, Cambridge, Massachusetts.
CHESTERMAN, CHARLES W., 1311 Beale Avenue, Bakersfield, California.
CHUTE, NEWTON E., 44 Tremlett Street, Dorchester, Massachusetts.
CISTAR, LOUIS A., 129 Avenue B, Rochester, New York.
CLAFFY, MRS. ESTHER M., Room G-241-C, U. S. Geological Survey, Washington, D. C.
*COATS, ROBERT, Alaskan Branch, U. S. Geological Survey, Washington, D. C.
*COLBURN, BURNHAM S., Greystone Court, Biltmore, North Carolina.
*COLBURN, WILLIAM B., 720 South Lucerne Boulevard, Los Angeles, California.

*Connolly, Joseph P., 1804 West Boulevard, Rapid City, South Dakota.
Cook, Kathryn H., 3301 St. Paul Street, Baltimore, Maryland.
*Cooke, S. R. B., Montana School of Mines, Butte, Montana.
Cooley, Mary E., 793 South Forest Avenue, Ann Arbor, Michigan.
Cooper, John R., U. S. Geological Survey, 707 Peyton Building, Spokane, Washington.
*Corbett, Clifton S., 3634 Elbow Drive, Calgary, Alberta, Canada.
Corbin, L. P., Jr., 210 Tyler Street, Sandusky, Ohio.
Courtright, Hugh C., 4940 East End Avenue, Chicago, Illinois.
Cramer, Joe L., 938 South Ash Street, Wichita 9, Kansas.
Crawford, Arthur L., 1067 East Fifth Street South, Salt Lake City, Utah.
*Crawford, R. D., 1050 Tenth Street, Boulder, Colorado.
Cress, Samuel H., 1648 Park Road, N.W., Washington, D. C.
Crickmay, Geoffrey W., Box 549, Athens, Georgia.
Crippen, Richard A., Idria, San Benito County, California.
Cropper, Wallace J., 4410 Cayuga Avenue, New York 63, New York.
Crunden, A. B., 54 Edgemont Road, Montclair, New Jersey.
Cummins, A. B., 602 East Front Street, Plainfield, New Jersey.
*Currier, Louis W., U. S. Geological Survey, Washington, D. C.
Cuthbert, F. Leicester, Soil Science Laboratory, Dept. of Civil Engineering, Princeton University, Princeton, New Jersey.

Dake, H. C., 703 Couch Building, Portland, Oregon.
Daley, A. Cowles, 1191 North Los Robles, Pasadena, California.
Darneal, Robert L., P.O. Box 94, Stanford University, California.
Davidson, Norman, 5611 Fifth Street, N.W., Washington 11, D. C.
Davidson, Stanley C., 152 Wembley Drive, Sudbury, Ontario, Canada.
Davis, Donald W., Scarsdale Manor Apts., R-North, Scarsdale, New York.
Davis, Harry T., North Carolina State Museum, Raleigh, North Carolina.
Denning, Reynolds M., 843 Thurston Road, Rochester, New York.
Dennis, William Engs, Jr., Box 373, Newport, Rhode Island.
Denny, M. V., Mineralogical Laboratory, University of Michigan, Ann Arbor, Mich.
Derr, Herman, 329 N.W. 13 Street, Oklahoma City, Oklahoma.
Desmond, Thomas C., 941 Broadway, Newburg, New York.
Dietz, Robert S., Army Air Force Navigation School, Hondo, Texas.
Dodge, Theodore A., Cananea Consolidated Copper Company, Cananea, Sonora, Mexico.
*Donnay, Joseph D. H., 2926 New Road, Roselle, Wilmington, Delaware.
Douglas, Gordon S., 2201 Georgiana Avenue, Santa Monica, California.
Doyle, C. C., San Francisco Mines of Mexico, Ltd., San Francisco del Oro, Chihuahua, Mexico.
Draeger, R. H., Captain (MC), U.S.N. Naval Medical Research Institute, Bethesda 14, Maryland.
Draisin, Wilburt M., Majestic Radio & Television Company, 2600 West 50 Street, Chicago, Illinois.
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University of Pretoria Library, Pretoria, South Africa.
University of Rochester Library, Rochester, New York.
University of St. Andrews Library, St. Andrews, Scotland.
University of Sheffield, St. George's Square, Sheffield 1, England.
University of South Dakota Library, Vermilion, South Dakota.
University of Southern California Library, University Park, Los Angeles, California.
University of Sydney, Fisher Library, Sydney, New South Wales, Australia.
University of Tennessee, Knoxville, Tennessee.
University of Texas Library, Austin, Texas.
University of Toronto Library, Toronto, Ontario, Canada.
University of Utah Library, Salt Lake City, Utah.
University of Virginia Library, Charlottesville, Virginia.
University of Washington Library, Seattle, Washington.
University of Washington, College of Mines, 324 Mines Laboratory, Seattle, Washington.
University of West Virginia Library, Morgantown, West Virginia.
University of Western Australia Library, Perth, Western Australia.
University of Wisconsin Library, Madison, Wisconsin.
University of Witwatersrand Library, Johannesburg, South Africa.
University of Wyoming Library, Laramie, Wyoming.

Valentine Garcia y Cia, Apartado 2103, Habana, Cuba.
Vanadium Corporation of America Library, Bridgeville, Pennsylvania.
Vanderbilt University, Joint University Library, Nashville, Tennessee.

Ward's Natural Science Establishment, 3000 Ridge Road East, Rochester, New York.
Washington State College Library, Pullman, Washington.

Washington University Library, St. Louis, Missouri.
Wayne Laboratories, 17 East Main Street, Waynesboro, Pennsylvania.
Wellesley College Library, Wellesley, Massachusetts.
Wesleyan College Library, 175 North Street, Middletown, Connecticut.
Wichita City Library, Wichita, Kansas.

Young, Henry, and Sons, Ltd., 15 North John Street, Liverpool, England.

NOTES AND NEWS

Bastnaesite at Corona, New Mexico

Information received from R. S. Dean, Assistant Director of the Bureau of Mines, indicates a tentative identification of the mineral bastnaesite, a fluocarbonate of the cerium metals, in the microscopic examination of a sample taken from the Red Cloud fluorite deposit at Corona, New Mexico. The sample was sent to the Rolla, Missouri, laboratory of the Bureau of Mines for ore-dressing tests and the identification was made by Waldemar M. Dressel, Jr., in the course of a routine microscopic examination of the material.

The bastnaesite occurs in small, short prismatic hexagonal crystals with a basal parting. They are yellow to brownish-yellow in color with a waxy to resinous luster. The hardness is 4 and specific gravity 5.018. Optically the material is uniaxial positive with omega slightly below 1.72 and epsilon very close to 1.82.

Qualitative chemical tests showed the presence of the cerium metals. Spectrographic analysis showed strong lines for cerium, praseodymium and lanthanum, with the possibility of neodymium as well.

By microscopic count the composite of the gravity concentrates contained approximately 35% of bastnaesite. On this basis the content of the head sample would be about 2.4%. The tentative identification of this rare mineral will be checked by a quantitative chemical analysis.

The following have been elected officers of the American Society for X-ray and Electron Diffraction: W. H. Zachariasen, department of Physics, University of Chicago, Vice-President for 1944 and President-elect for 1945, and J. D. H. Donnay, Laval University, Quebec, and Hercules Powder Company, Wilmington, Delaware, Secretary-Treasurer for 1944. Dr. L. H. Germer of the Bell Telephone Laboratories at Murray Hill, New Jersey, is president for 1944. The next meeting of the society will be a joint Research Conference with Section *C* of the American Association for the Advancement of Science next August at Gibson Island, Maryland.

By vote of the Executive Committee of the A.A.A.S., the Association will hold its annual meeting for 1944 in Cleveland, Ohio, during the week of September 11–16.

The Executive Committee passed the following resolution relative to the programs of the meetings:

"It was voted to bring to the attention of the Association and to all of the affiliated societies that in all programs of the September meeting emphasis be placed on the indispensability of science for the future of civilization, both in war and in peace."

The Association extends to all its affiliated and associated societies a cordial invitation to participate in the Cleveland meeting.

Dr. Edward Bennett Mathews, professor emeritus of mineralogy and petrography at Johns Hopkins University, died Feb. 4 at the age of 74 years. Since 1917 he had served as treasurer of the Geological Society of America.

Robert L. Darneal, A.B., San Jose (Calif.) State College, has been appointed Teaching Fellow in Mineralogy at Stanford University.

Professor Benjamin Leroy Miller of the Geology Department of Lehigh University died from a heart attack March 23, 1944, at the age of 69 years.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

The Academy of Natural Sciences of Philadelphia, December 2, 1943

A stated meeting of the Society was held with Dr. W. Hersey Thomas presiding. Sixty-seven persons were present.

Dr. William Parish addressed the Society on "The Role of Crystallography in the Manufacture of Quartz Oscillator Plates." The technique of proper orientation of quartz crystals by optical means and x-rays was described, also the control of the orientation during the manufacture as well as the method of sawing, lapping and finishing the plates to their nominal frequencies. By the newer procedures, the right hand and left hand character and polarity of the quartz are not determined; indeed, "electrical" twinning is so prevalent that such determinations are discouraged. The crystallographic properties of the quartz are used for automatic correct orientation, which at the same time insures maximum utilization of the raw material. The lecture was illustrated with specimens, lantern slides and a sound film prepared by the Reeves Sound Laboratories of N.Y. Quartz mining in Brazil was alluded to, and the methods of inspection for optical and electrical twinning were outlined.

Meeting of Jan. 6, 1944

Dr. W. Hersey Thomas presided, with 42 persons present.

Professor J. D. H. Donnay addressed the society on "The Symmetry of Crystals." He defined symmetry by means of the concepts of singular, polar or homopolar directions and discussed symmetry operations and symmetry elements, using the Hermann-Mauquin notation for symmetry symbols. After recalling the fundamental properties of the stereographic projection, he showed how all the faces of any form can be obtained by the symmetry operations available in the symmetry symbol of the crystal class.

Mr. Fred Oldach reported that the Franklin Graphite Co. had been working the Chester County graphite diggings near Anselma, Pa., and that a production of 350 tons of ore per day had been planned. This ore was expected to average 3 per cent graphite.

Meeting of Feb. 3, 1944

Dr. W. Hersey Thomas presided. Fifty-three members and visitors were present.

Dr. Clifford Frondel of Harvard University addressed the Society on "The Seventh Edition of *Dana's System*." This edition of Dana is to be in three volumes. The first volume which is now in the printer's hands is expected to appear in June.

This volume contains the elements, sulphides, sulpho-salts, oxides, hydrates, and such minerals as the tantalates, columbates and uranates. All data are thoroughly checked and must be of the highest character before they are acceptable. Such properties as variation in chemical composition, habits and twinnings of crystals, physical and optical properties are included, together with the types and occurrences of minerals, all of which are adequately described in the new edition. An effort was also made to uncover the origin of the names of minerals, an item which entailed much research work.

J. S. Frankenfield, *Secretary.*

BOOK REVIEWS

ERUPTIVE ROCKS, THEIR GENESIS, COMPOSITION, AND CLASSIFICATION, WITH A CHAPTER ON METEORITES. Second edition. By S. JAMES SHAND. New York, John Wiley & Sons; London, Thomas Murby & Co., **1943.** Pp. xvi+444; figs. 47, pls. 3. Price $5.00.

This second edition of Professor Shand's notable book has been extensively revised. The wide field and laboratory experience of the author and his many contacts with the points of view of petrologists of three continents, as a student in Scotland and as a teacher in South Africa and America, give him an unusually comprehensive grasp of the subject. This has resulted in a book which gives the best elementary treatment of the eruptive rocks that is in print. The author has a wide familiarity with the literature and lists many references at the end of each chapter. Throughout, the discussions are brief and critical, and they preserve an excellent balance between the field, the laboratory, and the geochemical data and arguments.

The first chapter deals with such properties of magmas as their fluidity, water content, and temperatures of consolidation. For the latter he boldly places the temperature of consolidation of extrusive rocks above 700° and those of most granular rocks from 700° to 500°. These temperatures are probably lower than would be given by most petrographers. At the time the quartz of the pegmatites was studied all of the pegmatites were thought to be magmatic, but our present knowledge indicates that all of the low quartz tested from pegmatites was hydrothermal and all of the magmatic quartz was high quartz. There is no convincing evidence that the temperature of crystallization of the extrusive rocks is much, if any, higher than that of the granular rocks with the same composition.

The second chapter deals with the minerals and mineral families in the eruptive rocks and the relative abundance of the oxides and elements. The descriptions of the mineral families deals chiefly with their chemical compositions and artificial formation. It recognizes the complexity of the rock minerals and explains this on the modern theory of atomic substitution. The descriptions are brief, but they are clear and accurate and so are suitable for an elementary student.

Chapter 3 deals with the fugitive constituents and is a well-balanced discussion of the field, laboratory, and geochemical data.

Chapter 4 discusses the temperature and pressure in the magma. The discussion is excellent. However, the reviewer has concluded both from a study of the literature and from personal observations that inversion of quartz to tridymite by magmatic heat is very rare, and we still need clear evidence that it takes place. The data on the effect of pressure on the high-to-low-quartz inversion is accurately known. The curve of Goldschmidt on the effect of pressure on the reaction $CaCO_3+SiO_2 \rightleftarrows CaSiO_3+CO_2$ has little value as the pressure involved is the vapor pressure of CO_2 and this may be low since the CO_2 escapes as the reaction takes place.

Chapter 5 on the freezing of the magma presents chiefly the physico-chemical data. Chapter 6, on the magma and its walls, places reasonable emphasis on reaction and assimilation by the magma. Chapter 7, on the order of crystallization, fails to give sufficient emphasis to the natural chilling experiments prepared for us by nature in the lavas and small intrusive bodies. Chapter 8 deals with compatible and uncompatible phases and Chapter 9 with eruptive rock complexes.

The next ten chapters deal with the classification and description of rocks and with problems that concern chiefly one group of rocks. After a general discussion of rock classification, the author presents his own system. The major divisions are based on the rather obvious and commonly used silica content—oversaturation, saturation, or undersaturation. The next subdivision is based on the alumina content with respect to that required to form feldspars and feldspathoids. Does a broad study of rocks justify such great importance being given to alumina? Next are four divisions depending on the proportion of dark minerals. Then four divisions based on the proportion of the different feldspars or feldspathoids: or>an and or>ab; or>an and or<ab; or<an and ab>an; and or<an and ab<an.

Shand's system of classification seems to differ materially in many respects from that in common use, yet rock names are used by Shand with much the same meaning as in other systems.

Shand's book is very well written. It does not present the material dogmatically but gives the arguments pro and con clearly and concisely. The reader is shown the complexities and uncertainties that are inherent in nearly all petrological problems.

The repeated use of the terms acid and basic rather than silicic, or some other more appropriate terms, and the use of alkaline for alkalic will be unwelcome to many American petrographers who have been attempting to discourage the use of these inappropriate terms.

The philosophical quotations at the beginning of each chapter are apt.

Esper S. Larsen
Harvard University.

LUMINESCENCE OF LIQUIDS AND SOLIDS and its Practical Applications. By Peter Pringsheim of the Department of Chemistry, University of Chicago, and Marcel Vogel, San Francisco, California. x+201 pages. Interscience Publishers, Inc., New York, N. Y. (**1943**). Price $4.00.

Part I of this book is devoted to "Physics of Luminescence." This section includes a brief chapter on the history of luminescence, after which the theory of luminescence is well discussed. Then follow chapters devoted to a description of the various types of light sources for producing photoluminescence, a discussion of photometric instruments for measuring the intensity of luminescence and its duration, spectroscopic methods for examining the light produced, and on the use of the microscope in examining fluorescent materials. In chapter IV of section I are discussed luminescent materials, both organic and inorganic. Synthetic inorganic phosphors are described in considerable detail and methods of preparing many of them are given. The reviewer finds no mention of the interesting fused mixtures of certain iodides, such as cadmium and manganese iodides. Rather little space is devoted to the fluorescence and phosphorescence of minerals because of the limited number of useful applications in this field. The fluorescence of scheelite is, however, rather extensively employed in prospecting for calcium tungstate and the fluorescence of willemite is also being utilized.

In Part II, 34 pages are devoted to the fluorescence analysis, both qualitative and quantitative, of organic and inorganic materials, including the use of fluorescent indicators and the determination of vitamins B_1 and B_2.

The last chapter is devoted to luminescence as a light source, including fluorescent and phosphorescent paints and screens, and fluorescent lamps. A long list of important organic and inorganic fluorescent compounds, with their properties and references to them, is included.

References to the literature are quite complete and greatly increase the value of the book. The general appearance and style of the book are good.

Although this book is of limited direct usefulness to mineralogists, the wide variety of uses of luminescent materials will make this book very interesting reading and a valuable text of reference to scientific workers in this and many other fields.

H. H. Willard
Dept. of Chemistry,
University of Michigan.

CHRONIC PULMONARY DISEASE IN SOUTH WALES COALMINERS, II, ENVIRONMENTAL STUDIES. A Report by the Committee on Industrial Pulmonary Disease. B.-G. Reports on Physical, Chemical and Petrological Studies. By T. Bedford and C. G. Warner; H. V. A. Briscoe, P. F. Holt, N. Spoor and others; G. Nagelschmidt; A. Brammall and J. G. C. Leech; D. Hicks and G. Nagelschmidt; J. Ivon Graham and D. F. Runnicles; and co-workers. 222 pages, *London*, His Majesty's Stationery Office **(1943)** Price 10s.6d.

The report on environmental studies is complementary to a previous report covering a medical survey and accompanying pathological studies issued a year earlier (Spec. Rep. Ser. Med. Res. Coun. London., #243, 1943). It will be found of value to students of silicosis, to workers in the petrology of sediments, and particularly to those interested in the mineralogy of clay and shale.

This report has been prepared under the direction of the Committee on Industrial Pulmonary Disease but is essentially restricted to environmental studies. The term "environmental conditions" is intended to embrace such features as dust breathed at the coal face, the nature and size of the dust particles, the composition and characteristics of the strata mined, irritant fumes of explosives, temperature and humidity of the air. Due to the broad scope of the investigation, it has been of necessity the product of the joint work of a large group.

The medical survey showed that the pulmonary abnormality encountered among coal miners could be found throughout the South Wales field; its incidence and severity being greatest in the case of miners who had worked for long periods at the coal face in the anthracite mines. The incidence of pulmonary abnormality was shown to vary with the rank of coal mined, allowing for certain local exceptions in the anthracite area. The disease of the South Wales coal miners, although a "disabling pulmonary disease" did not come within the accepted definition of "silicosis." Prolonged exposure to air-borne dust is given as the most important causative factor in the *pneumokoniosis* of coal workers.

The method of thermal precipitation previously described by Greene and Watson was used for the collection of dust samples. In this method particles are precipitated on glass slides due to the action of an electrically heated wire operating in an air current drawn directly from the air zone under examination. The glass slides containing the particles were studied under the microscope, making use of the oil-immersion objective and high magnification. According to Nagelschmidt, x-ray diffraction analysis can be considered as a substitute for microscopic analysis for mineral particles too small to be examined with the microscope.

According to the committee it is generally agreed that silicosis due to quartz dust may be attributed to particles which are less than five microns in diameter. Hence, it is concluded that the cause of *pneumokoniosis* among coal miners is to be found in the accumulation of the smaller particles in the air breathed.

Hicks and Nagelschmidt furnish the results of chemical and x-ray diffraction analyses of the mineral matter of coal seams, the adjacent strata, the air-borne dusts and screened fractions of the mined product. The quartz content of the rocks and dusts varies but shows no clear relationship to the rank of coal or *pneumokoniosis* incidence. In the mineral matter of the coal seam kaolin and carbonates predominate, while mica (illite) and quartz predominate in the rock strata. The dusts and screened fractions show these constituents and are similar to each other.

The sodium content of the mica in the rock decreases in passing from anthracite to bituminous coal. At the same time in the mineral matter of the coal seam the kaolin mineral changes from halloysite to kaolinite. The amount of kaolin and carbonates in the ash also undergoes increase. Notwithstanding these mineral changes the coal itself should be studied since the dust of anthracite may prove a greater hazard than bituminous dust.

Brammall and Leech furnish a detailed petrographic description of the rock strata overlying the coal. Differences in the degree of compaction and metamorphism establish a contrast between the shales of the bituminous and anthracite region. Anthracite, as would be expected, is associated with the higher pressure conditions.

A fairly complete suite of clay minerals is described in the clay-shal-slate sequence. The occurrence in the South Wales shales of primitive white mica (hydromuscovite, sericite or illite) is recorded. In addition both kaolinite and dickite are present in considerable abundance.

Petrologically the samples examined fall into two contrasted groups: (1) those from three non-anthracite mines, (2) those from anthracite mines. The chief contrast between the two groups lies in the degree of metamorphism that has been brought about by pressure.

PAUL F. KERR, *Columbia University.*

PAPERS PUBLISHED IN THE BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA OF SPECIAL INTEREST TO MINERALOGISTS

The following list of papers of special interest to mineralogists appeared in the July–December numbers of the *Bulletin of the Geological Society of America.* As indicated below some of these papers may be secured by writing to the Secretary of the Geological Society of America, 419 West 117th St., New York, N. Y.

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	Price
Archean sedimentation. By F. J. Pettijohn, pp. 925–972.	.45
Spectrographic analysis of New England granites and pegmatites. By John A. Shimer, pp. 1049–1066.	.15
Application of geology to the principles of war. By Charles E. Erdmann, pp. 1169–1194.	.20
Metamorphism of extrusives by basic intrusives in the Keweenawan of Minnesota. By G. M. Schwartz, pp. 1211–1226.	.15
Packing in ionic minerals. By H. W. Fairbairn, pp. 1305–1374.	.40
Recrystallization and flowage in Appalachian quartzites. By Robert E. Fellows, pp. 1399–1432.	.35
Plagioclase twinning. By J. D. H. Donnay, pp. 1645–1652.	*
Unusual lamprophyric dikes in the Manhattan schist of New York City. By R. J. Colony and H. R. Blank, pp. 1693–1712.	*
Transportation and deposition of heavy minerals. By Gordon Rittenhouse, pp. 1725–1780.	*

* The Geological Society has discontinued stocking reprints, but separates may be available from the author's supply.